LEBM0041-00
April 2016

Project Guide

C7.1 Marine Propulsion Engine

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards, including human factors that can affect safety. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product until you verify that you are authorized to perform this work and have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the “Safety Alert Symbol” and followed by a “Signal Word” such as , “WARNING”, “Caution”, or ‘‘Note’’. The Safety Alert “WARNING” label is shown below.

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

A non-exhaustive list of operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. You must not use this product in any manner different from that considered by this manual without first satisfying yourself that you have considered all safety rules and precautions applicable to the operation of the product in the location of use, including site-specific rules and precautions applicable to the work site. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that you are authorized to perform this work and that the product will not be damaged or become unsafe by the operation, lubrication, maintenance or repair procedures that you intend to use.

⚠ WARNING

When replacement parts are required for this product Caterpillar recommends using Cat replacement parts.

Failure to follow this warning may lead to premature failures, product damage, personal injury or death.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Cat dealers have the most current information available.

In the United States, the maintenance, replacement, or repair of the emission control devices and systems may be performed by any repair establishment or individual of the owner’s choosing.

C7.1 Marine Propulsion Engine Project Guide

Introduction

The aim of this publication is to provide information in the form of technical data and installation guidance, enabling engines to be installed in a manor which will ensure safety, reliability and ease of servicing.

Note: Failure to follow these instructions when installing a certified engine in a vessel violates federal law (40 CFR 1068. 105(b)).

Only install and operate this engine in accordance with the specifications and parameters of the stated model.

Contents

1. Location of Engine Installation Points

Heat Exchanger

Front and Right Side

1 Lubrication oil filler cap.

2 Electronic Control Module (ECM).

3 Belt cover.

4 Cabin heater, outlet (optional).

5 Cabin heater, inlet (optional).

6 Auxiliary water pump.

7 Raw water intake.

8 Fuel inlet.

9 Fuel return.

10 Aftercooler drain valve.

11 Aftercooler.

12 Air intake.

13 Crankcase breather.

14 Fuel filter, secondary.

15 Oil filter.

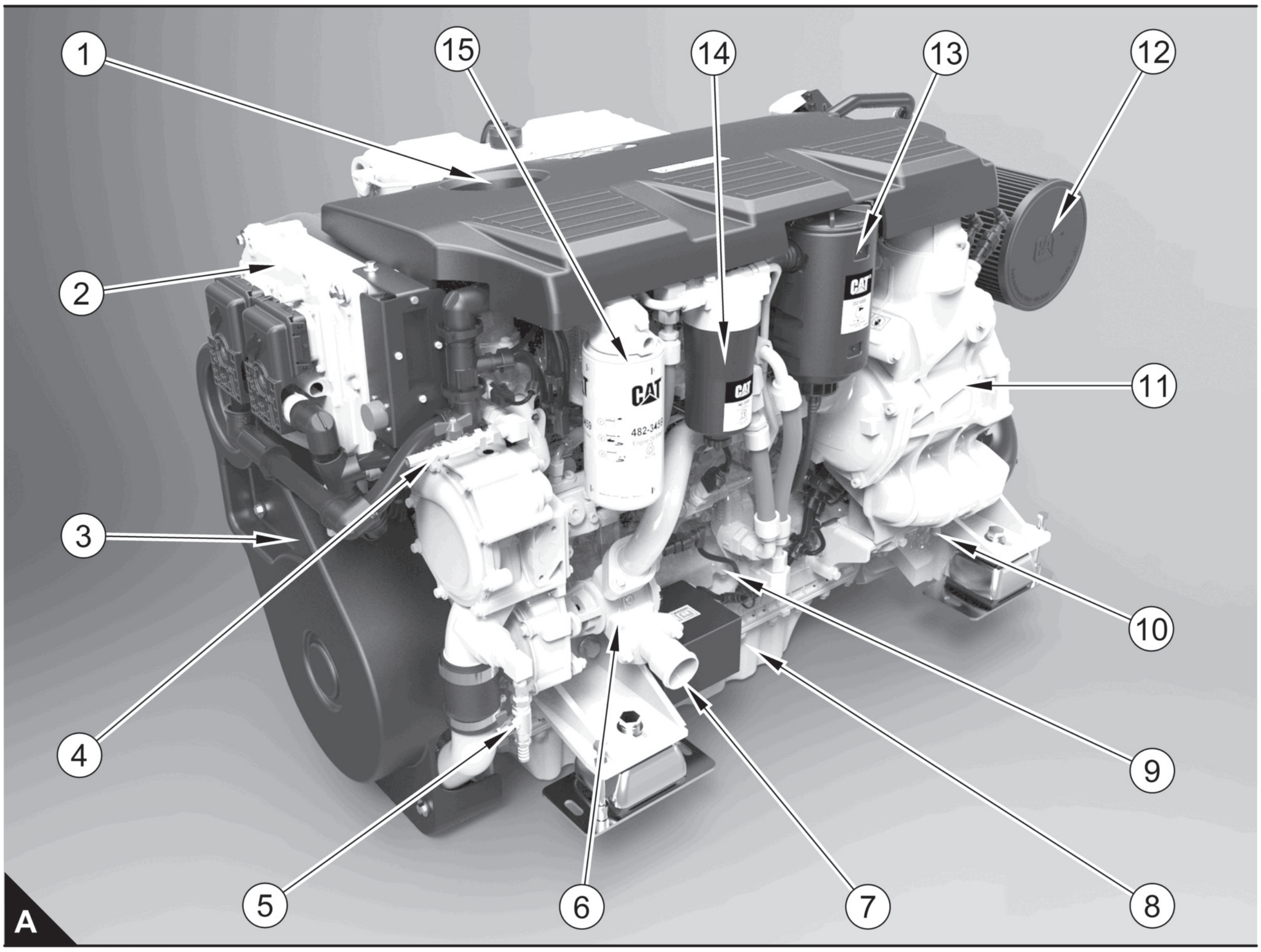


Illustration IM71P01

Rear and Left Side

16 Starter motor.

17 Lubricating oil drain.

18 Dipstick.

19 Flexible and adjustable engine mounts (optional).

20 Gearbox oil cooler (optional).

21 Header tank/heat exchanger.

22 Front lifting eye.

23 Exhaust manifold.

24 Rear lifting eye.

25 Turbocharger.

26 Air filter.

27 Water cooled exhaust elbow (optional).

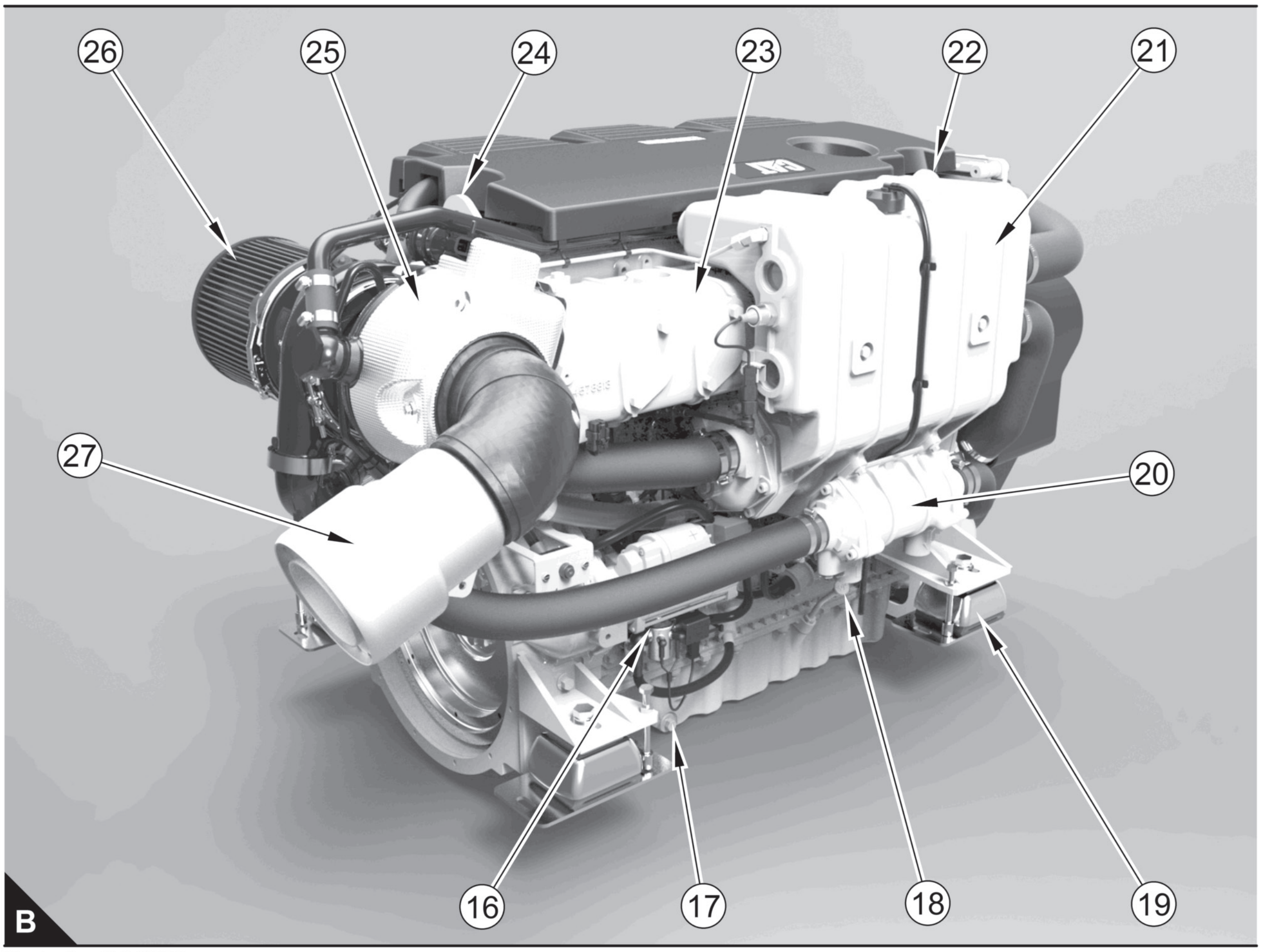


Illustration IM71P02

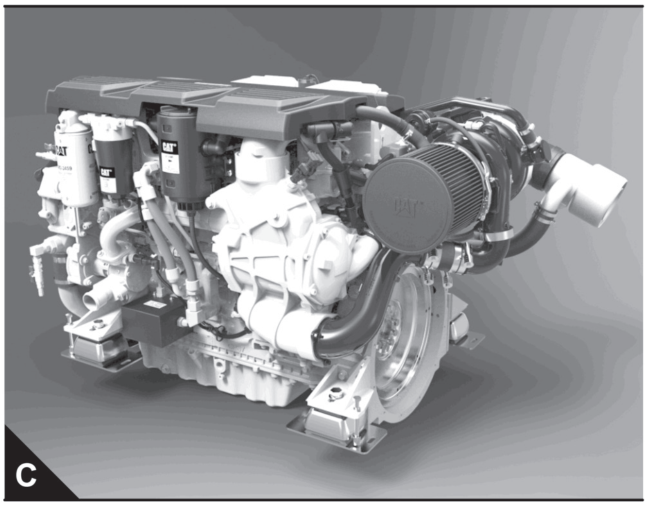


Illustration IM71P03

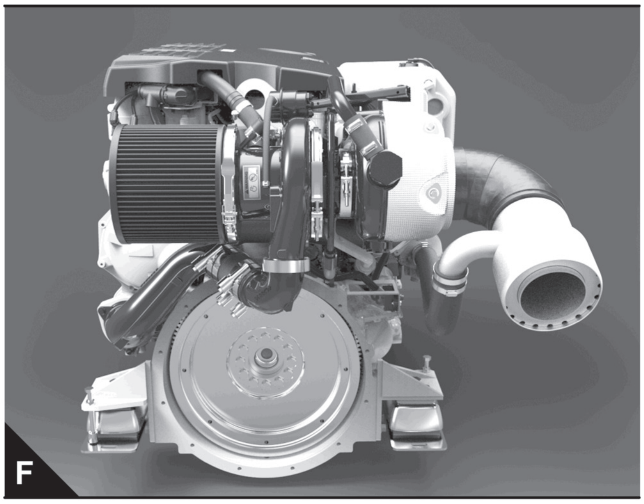


Illustration IM71P06

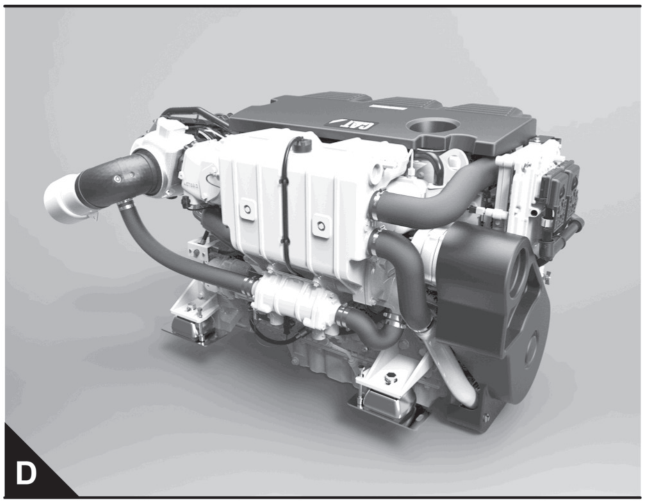


Illustration IM71P04

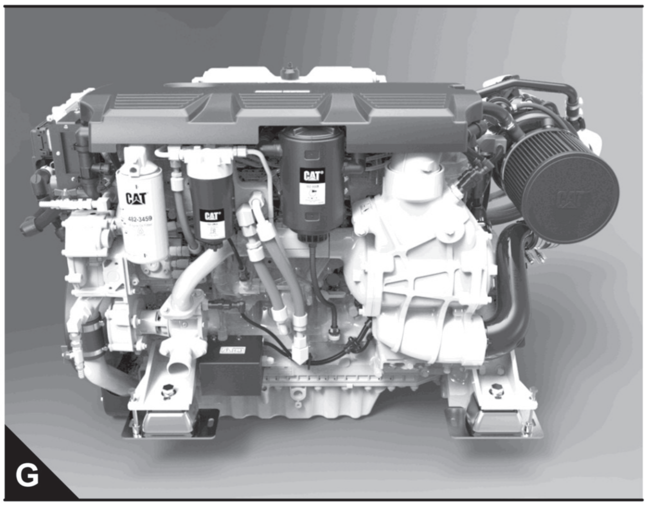


Illustration IM71P07

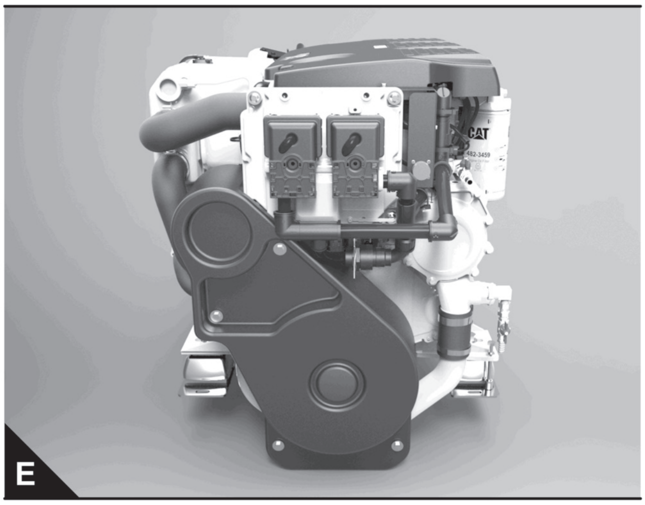


Illustration IM71P05

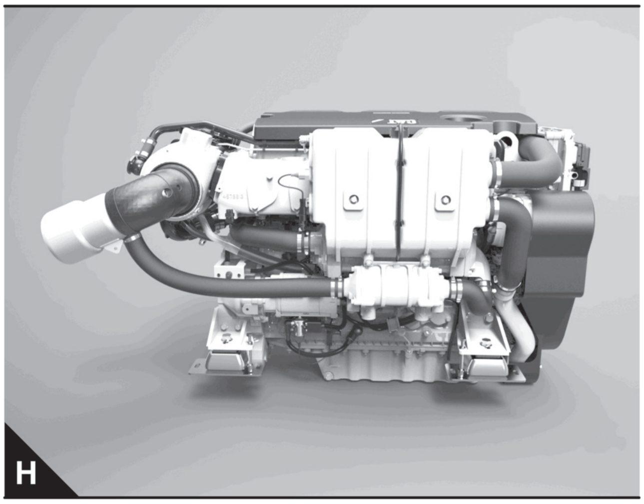


Illustration IM71P08

2. Engine Mounting

Caution: There must be sufficient space around the engine to avoid any contact with any surrounding vessel structure to avoid damage.

Caution: Do not exceed the minimum and maximum installation angles quoted in this project guide.

Caution: Any mounts supplied by the end user must comply with the manufacturers specifications.

Caution: Where the engine is mounted must be of sound and strong construction so as not to put additional stress and vibration on the unit and vessel.

Note: If the engine is installed in such a way that makes the engine's emission control information label hard to read during normal engine maintenance, a duplicate label must be placed on the vessel.

Installation Angles

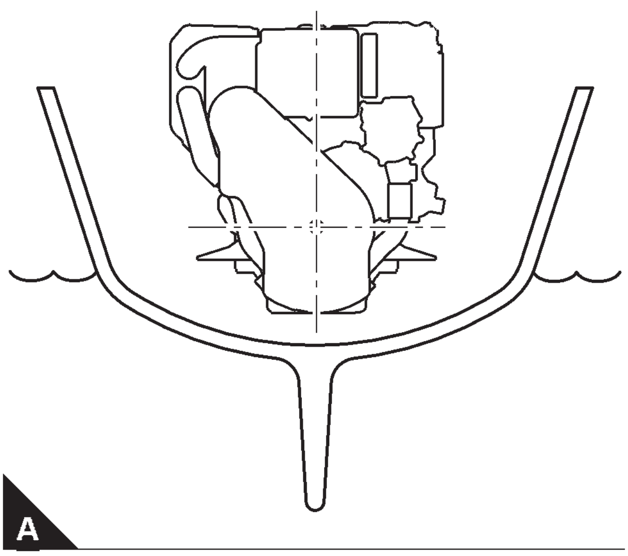


Illustration IM7130

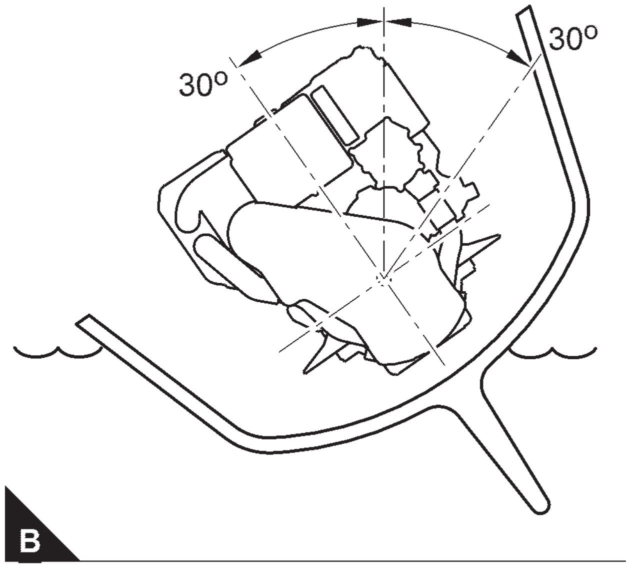


Illustration IM7131

These engines are intended to be mounted so that the cylinders are vertical, when viewed from ahead or astern as in (A). Maximum dynamic angle of 30^{o} is permitted athwart ships (B).

Illustration (C) shows the static installation angle fore and aft of 20^{o}.

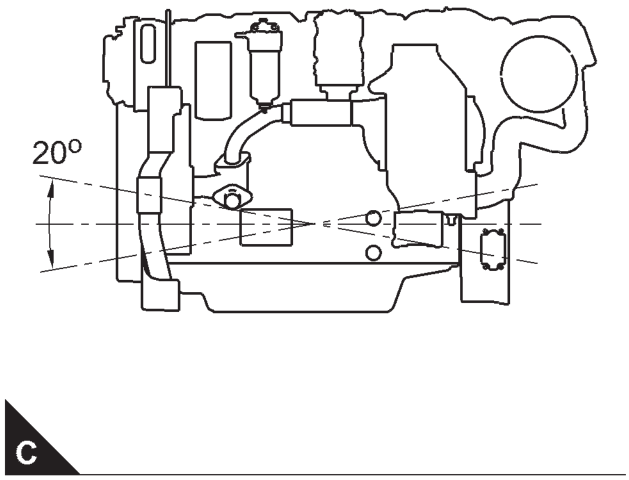


Illustration IM7220

Engine Mounting Brackets

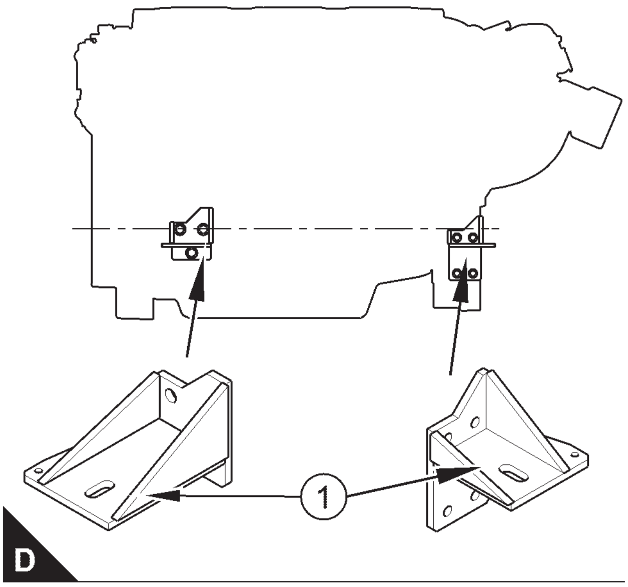


Illustration IM7219

The standard brackets, provide mounting points which are 51 mm (2”) below, and parallel with, the crankshaft centre line. The brackets may be used to mount the engine directly on the engine bearers, but for all applications it is recommended that flexible engine mounts are used.

Illustration (D) shows the holes (1) for the holding down bolts are slotted, 23 mm (centre to centre) x 17 mm diameter (0.9 x 0.67”) to allow for some movement during the final stages of alignment. Where fine alignment is not necessary, for example when a flexibly jointed drive shaft is used, the bolts on all four corners of the engine should be positioned at the end of the slot - all either fully in or fully out. This will provide additional security in the fixing arrangements.

Note: Please refer to the GA (General Arrangement) drawings for specific engine mount positions.

For any non standard options, please contact your local Caterpillar dealer for advice.

Flexible Engine Mounts

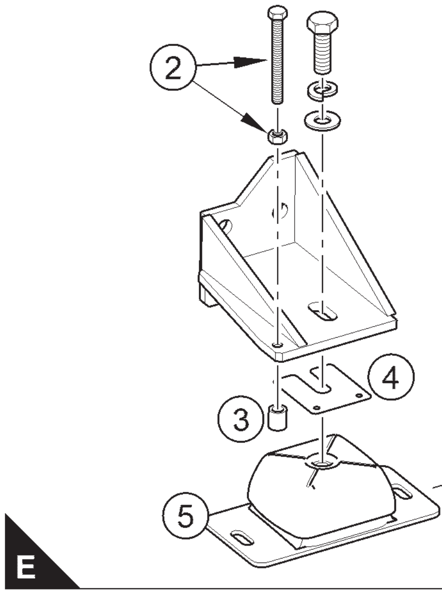


Illustration IM7221

It is recommended that flexible engine mounts should be used for all applications. The principal purpose of the mounts is to reduce the transmission of vibration from the engine to the hull, but another valuable advantage is that the mountings reduce the shock transmitted from the hull to the engine under adverse weather conditions and also prevent the engine being inadvertently used as a structural part of the boat, due to flexing in the hull, a function the engine will not satisfactorily fulfil.

Illustration (E) shows the flexible engine mount for most applications.

Note: Refer to the installation drawing for specific dimensions, which are for the mount in the unloaded condition.

To adjust the height of the mount (1), use the adjuster nut and bolt (2) against the pad (3) to introduce shims (4). A maximum of thirteen shims per mount can be used, eleven at 1 mm thick and 2 at 0.5 mm thick.

Caution: Jacking bolts must not be used to support the weight of the engine in service. The engine should be secured to the flexible mount through the shim packs and the main mounting bolt.

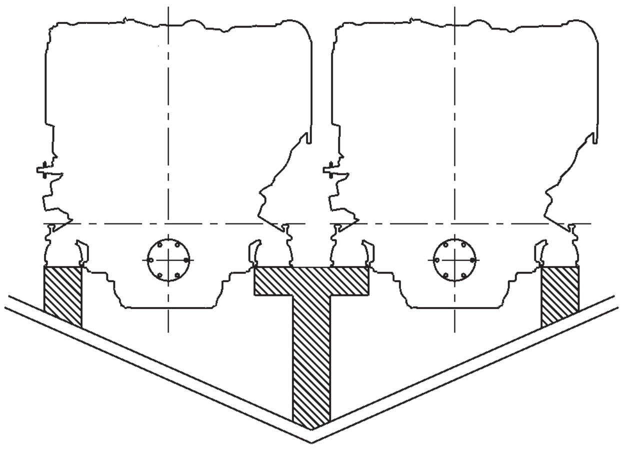
Radially slotted holes (5) can be utilised to obtain the optimum position.

Engines used with unusual drive arrangements, such as ‘V’ drives when integral with the engine unit, pose special mounting problems and recommendations as to the most suitable mounting arrangement can be made for specific applications.

Note: For transmission ratios above 2:1 or use in extreme conditions, please contact your local dealer for advice.

Installation drawings are available showing the preferred mounting arrangements when using a variety of gearboxes and applications.

Engine Bearers



F

Illustration IM7222

The materials and methods of construction of engine bearers which have proved to be satisfactory in service vary to such an extent that it is difficult to lay down universal guide lines. However, as a rough guide it can be said that the engine bearers should be capable of supporting a static load of about eight times the weight of the engine, to cater for the effects of rough seas.

The bearers should be cross connected to give lateral rigidity, in order to maintain the shaft alignment and to prevent twisting and racking forces being applied to the engine.

To enable minimum shaft centre distances to be achieved in a twin installation, a common centre bearer supporting the inner mountings of both engines is sometimes used as shown in illustration (F).

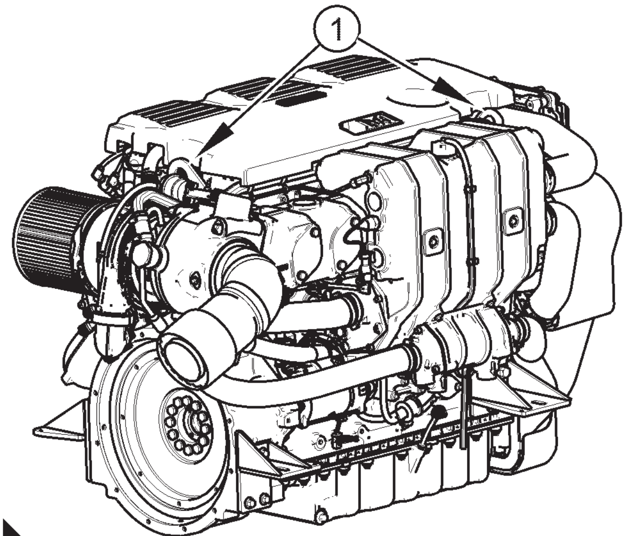
A recommended minimum distance between the shaft centres is 914 mm (36 inches).

Note: Narrower distances can be used but it must be noted that this will severely compromise serviceability.

Lifting

Lifting the Engine

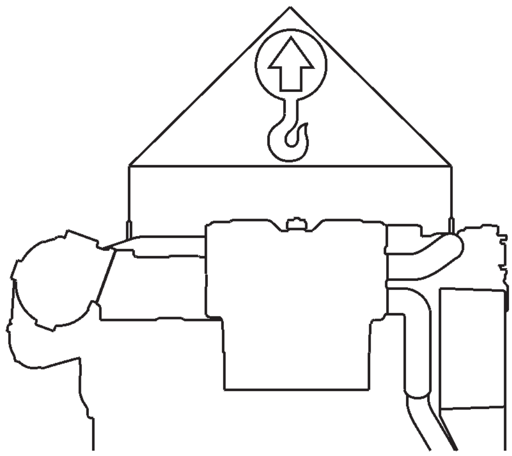
Caution: Care must be taken when lifting the engine when using strops as damage may occur if the pathway for the strops is too close to parts of the engine prone to damage.



G

Illustration IM7141

Lifting points have been provided (G1) for lifting the engine.



H

Illustration IM7185

Caution: Never bend the eyebolts and the brackets. Only load the eyebolts and the brackets under tension. Remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90 degrees. When it is necessary to remove

a component at an angle, only use a link bracket that is properly rated for the weight.

Use a hoist to remove heavy components. Use an adjustable lifting beam to lift the engine as shown in illustration (H). All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted.

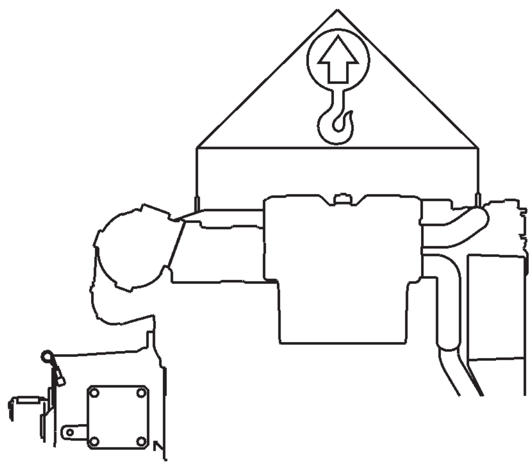
Some removals require lifting fixtures in order to obtain proper balance. Lifting fixtures also help to provide safety.

To remove the engine ONLY, use the lifting eyes that are on the engine.

Lifting eyes are designed and installed for the specific engine arrangement. Alterations to the lifting eyes and/or the engine make the lifting eyes and the lifting fixtures obsolete. If alterations are made, ensure that proper lifting devices are provided. Consult your Caterpillar dealer for information regarding fixtures for proper engine lifting.

Lifting the Engine and Transmission

Note: If the engine is equipped with a pod drive unit, refer to the information which is provided by the manufacturer of the pod drive unit.



I

Illustration IM7186

Caution: Do not use the eyebolts that are on the marine transmission housing to lift the engine.

To remove both the engine and the marine transmission, use the lifting eyes that are on the engine. Use an adjustable lifting beam to lift the engine. All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted. Consult your Caterpillar dealer or consult the OEM for information regarding fixtures for proper lifting of your complete package.

Lifting the Marine Transmission

To remove the marine transmission ONLY, use the eyebolts that are on the marine transmission housing. Refer to the manufacturers gearbox manual for proper lifting instructions (if equipped).

If a component resists removal, ensure that all of the nuts and bolts have been removed. Ensure that no adjacent parts are interfering.

4. Engine Room Ventilation

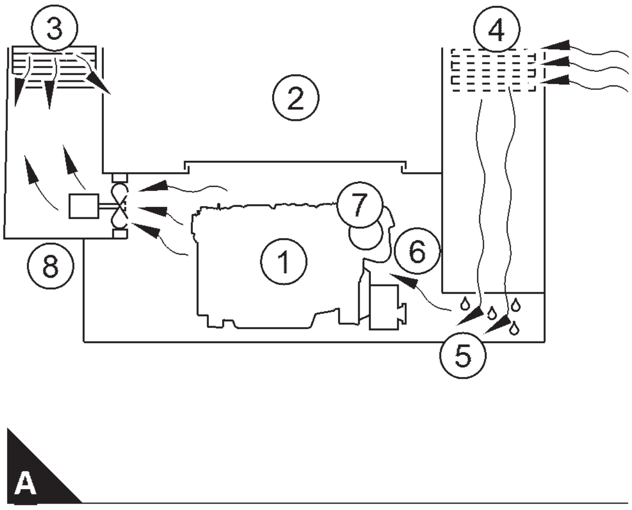


Illustration IM7144

1 Engine.

2 Cockpit.

3 Exhaust vent(s).

4 Inlet vent(s).

5 Moisture trap.

6 Engine rear.

7 Turbo air inlet.

8 Exhaust fan.

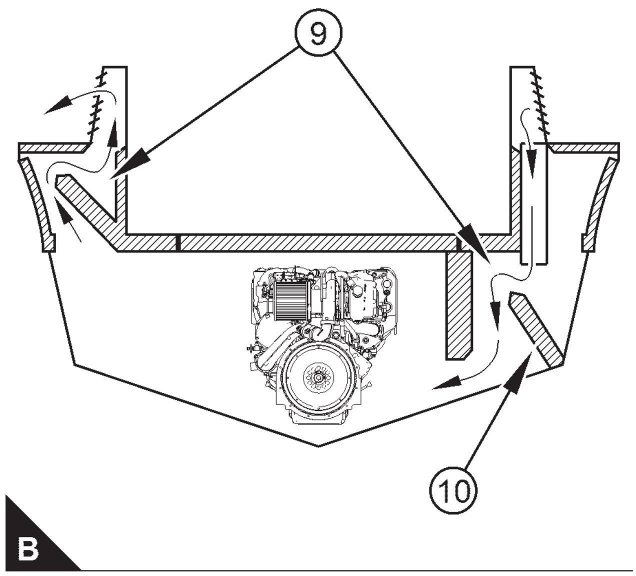


Illustration IM7193

9 Noise absorbing chambers.

10 Noise absorbant material.

Note: The air temperature entering the engine should not exceed 50°C. The air temperature in the engine room should not exceed 60°C.

Note: The maximum engine compartment depression is 1kPa.

Note: Cross sectional area of air flow path must not be too small.

The engine room must be ventilated for two reasons:

- To supply the engine with air sufficient for combustion.
- To provide a flow of air through the engine room to prevent an excessive temperature build-up which may cause components such as the alternator to overheat.

In most applications in temperate climates, the engine will draw air from the engine room. If this is the case then, as a rough guide, it can be taken that every horsepower produced by the engines requires, as a minimum, 161 sq. mm, (6.34 sq.ins.) of vent area. If the boat is likely to be used in hot climates, and if engine room ventilation fans are fitted, then a vent area of 322.58 sq.mm (12.7 sq.ins.) per horsepower should be provided. Wherever possible a flow of air through the engine room should be encouraged by using forward facing intake vents to take advantage of ram airflow, together with other vents to allow hot air to escape.

In most applications in climates up to around 40°C, the engine (1) can be allowed to draw combustion air from the engine room. In climates above 40°C it is strongly advised that the combustion air should be ducted to the air inlet from outside the engine room. The maximum engine air inlet temperature is 50°C.

Ventilation around the engine is required to remove radiated heat in order to stop the engine room temperature from rising too high. An effective ventilation system will keep the engine room temperature less than 10°C higher than external ambient.

Air entry vents (4) should be situated where spray is not likely to enter them and some form of water trap (5) is desirable. Preferably the air ducts should reach the engine compartment at the sides of the hull so that water will fall into the bilge. Ideally the air should enter the engine room at the rear of the engine (6), such that the turbocharger inlet (7) receives cool combustion air. Air inlet vents should be positioned to prevent exhaust air from being drawn in.

Where forced air is required for ventilation, (recommended in most installations), the air should be exhausted from the engine room using a suitable fan (8). Sucking the air from the engine room will ensure there is a slightly negative pressure present in the engine room. This prevents any air from the engine room escaping into the vessels cabins or living spaces, which could introduce smells and exhaust fumes.

Note: that the maximum engine room depression is 1kPa.

Where possible, individual exhaust suction points should be located directly above the primary heat sources. This will help to remove heat prior to it having a chance to mix with engine room air and raise the average temperature. In practice this is unlikely to be possible, and as such it is suggested that the air is exhausted from in front of the engine as shown.

If engine noise is of concern, noise absorbing chambers (9) with deflector baffles and noise absorbent material (10) can be positioned to direct ventilation air flow over a large surface area of the absorbent material. This can be applied to both inlet and exhaust ducts, significantly reducing noise emanating out through the vents.

When the engine is shut down after a run at high power the engine bay may become very hot, unless the ventilation fans are arranged to run-on after engine shutdown until the engine room is cool. In installations where living spaces and cabins are located close to the engine room, this can be of significant advantage.

Engine Drains

It is adviseable to attach a suitable container to 2 engine drains so that the fluids do not contaminate the bilge or floor of the vessel.

Both of these are found on the header tank/heat exchanger assembly (1).

- Heat exchanger drain (2). Attach a suitable remote container to the drain point with a tube.
- Header tank overflow pipe (3). Allow to drain into a suitable remote container.

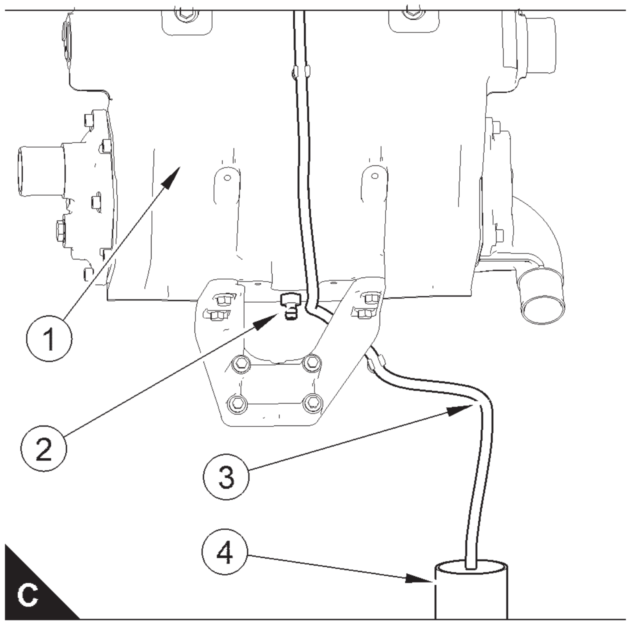
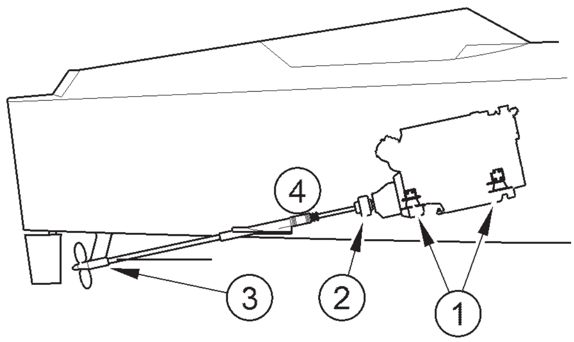


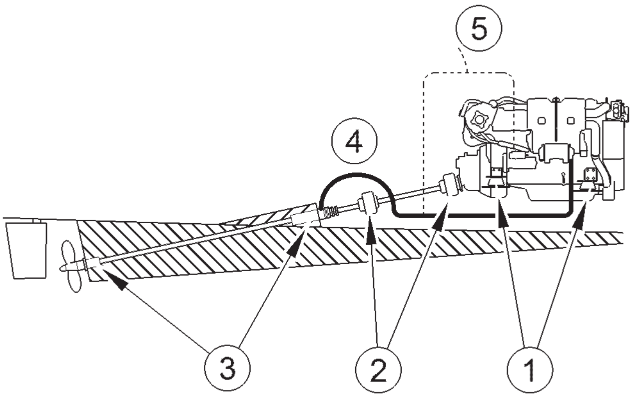
Illustration IM7235

Check the containers periodically and empty any excess fluid in accordance with local regulations.

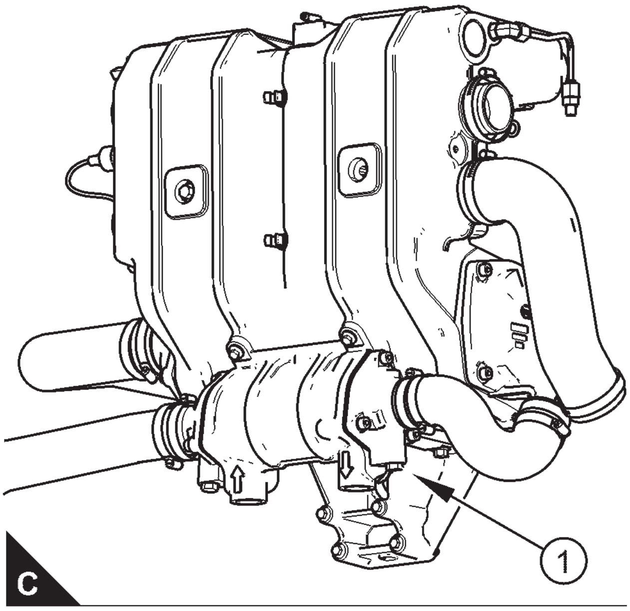
3. Propeller Shafts and Couplings



A
Illustration IM7223



B
Illustration IM7224



C
Illustration IM7233

It is recommended that all engines are mounted on flexible mountings (A1), which will reduce noise and vibration, and will prevent hull movements resulting in forces being applied to the engine.

The responsibility for the design and installation of the transmission system connected to the gearbox lies with the boat designer, the boat builder, the naval architect or the engine installer. It is recommended that a (TVA) Torsional Vibration Analysis is carried out on the complete drive system. Mass Elastic Data can be provided on request.

Illustration (A) shows a simple arrangement, where the propeller shaft is supported only by the gearbox coupling and an outboard rubber bearing at the propeller end. Entry of water into the boat is prevented by a shaft seal, which must be flexibly mounted to allow for engine movement. A flexible shaft coupling (A2) is fitted to the gearbox coupling, to allow momentary angular misalignment in operation

This system is only suitable for applications where the speed, diameter, and unsupported length of the propeller shaft will not induce ‘whirling’ (i.e. the centrifugal force generated by the speed of rotation is not sufficient to bend the shaft into a bow shape).

Illustration (A) also shows a cutless bearing (A3) and flexibly mounted shaft seals (A4).

Where the propeller shaft length is such that it cannot be simply supported by the gearbox coupling and ‘P’ bracket, without the risk of whirling, the arrangement shown in illustration (B) may be adopted

Water supply (B4) for bearings (use hose from 1/2” - 20 TPI STOR (Straight Thread O Ring) tapping on the gearbox oil cooler end cap) (C1).

In this case one or more additional bearings (B3) are included in the shaft log, and flexible shaft couplings (B2) (which will accept thrust) are used to permit the engine to move on the flexible mountings (B1).

WARNING

Use a syphon break (B5) where a water lift exhaust system is specified.

A variation of this is to use a thrust block (bearing) at the point where the shaft emerges from the log into the engine room, together with constant velocity joints at each end of the short shaft connected to the gearbox coupling.

Note: Customers that do not take the optional gearbox oil cooler, will have to provide this feed when they create the piping to their own gearbox oil cooler and exhaust elbow.

Propeller Sizing

The propeller is as important as the hull or the engine to the performance of the boat. The propeller directly influences top speed, fuel efficiency, and engine life.

While many operators will choose to operate at reduced throttle settings while cruising, the engine must be able to reach its rated speed (rpm) when the boat is ready for sea; fully loaded with fuel, water, and stores. To achieve the ultimate in engine life and economy, the engine should operate at approximately 2882 to 2940 rpm engine speed during sea trial of new vessels. This is done to compensate for anticipated boat loading and hull fouling. Full throttle engine speed should not be below 2853 rpm under normal in-service operating conditions.

5. Exhaust Systems
- Emission related installation instructions

Exhaust System Back Pressure

Note: that the system must meet the requirement for the maximum exhaust back pressure to be not greater than 15 kPa, measured within 305 mm (12 inches) of the turbocharger / exhaust outlet. Minimum volume of exhaust tank should be 3 times the volume of the water in the riser. The tank should be installed near the centre-line of sailing craft.

Excessive exhaust restriction can adversely affect performance, resulting in reduced power and increased fuel consumption, exhaust temperatures and emissions. It will also reduce exhaust valve and turbocharger life.

It is imperative that exhaust back pressure is kept within specified limits for those engines subject to emissions legislation. When designing an exhaust system, the design target for back pressure should be half the maximum allowable system back pressure. To ensure compliance, exhaust system back pressure must be verified to be within the Caterpillar EPA declared maximum value for the engine configuration and rating. Information (TMI) system, or contact your local Caterpillar dealer for more information.

Back pressure includes restrictions due to pipe size, silencer, system configuration, rain cap and other exhaust-related components. Excessive back pressure is commonly caused by one or more of the following factors:

- Exhaust pipe diameter too small.
- Excessive number of sharp bends in the system.
- Exhaust pipe too long.
- Silencer resistance too high.

1/8” BSP x M16 x 1.5 tappings are located in the dry exhaust outlet elbow (if supplied) for measuring exhaust back pressure.

The exhaust system should conduct exhaust gases from the engine to the atmosphere with acceptable back pressure at the same time reducing exhaust noise to the minimum, avoiding gas leaks and excessive surface temperatures while accommodating engine movement on flexible mounts.

Wet Systems

Note: that the system must meet the requirement for the maximum exhaust back pressure to be not greater than 15 kPa, measured within 305 mm (12 inches) of the turbocharger / exhaust outlet. Minimum volume of exhaust tank should be 3 times the volume of the water in the riser. The tank should be installed near the centre-line of sailing craft.

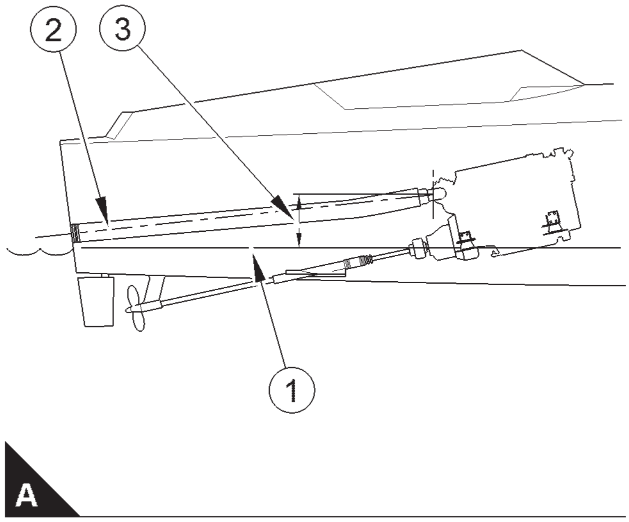


Illustration IM7225

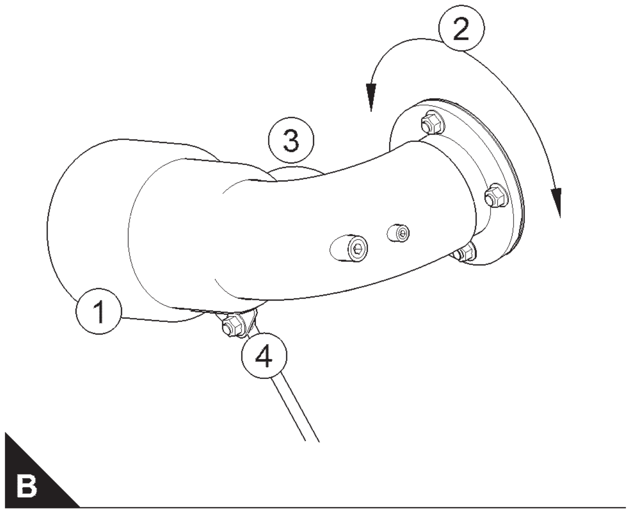


Illustration IM7226

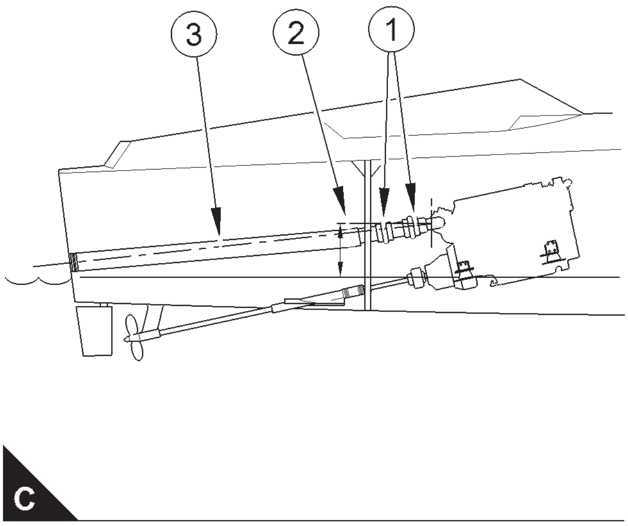


Illustration IM7227

Wet exhaust systems, where the auxiliary water used to circulate through the heat exchangers on the engine is finally dumped into the exhaust pipe to cool the exhaust gases, are the most common choice for small craft. Their principal advantage is that a rubber exhaust hose may be used, with a fairly low surface temperature, which presents no risk of fire.

The exhaust elbow outside diameter is 152.4 mm (6”).

A general arrangement for such a system is shown on illustration (A). In many cases the exhaust outlet passes through the transom, just above the waterline (A1). It will be seen that a minimum fall of 5^{O} (A2) is required, and that the point of water injection must be at least 8 inches above the waterline (A3), although the actual height necessary for a particular boat can only be decided in the light of the exhaust system design, and the pitch and roll which may be encountered in service.

***Caution:* It is essential that the exhaust system is designed so that water from the exhaust does not enter the engine under any conceivable operational condition.**

Illustration (B) shows the exhaust elbow (B1) with water injection (B3) and support eyelet and support (B4). The elbow can be rotated (B2) to achieve the optimal position.

Note: The exhaust elbow must have a fall of 10^{O} downwards.

The wet exhaust elbow is fitted with an eyelet (B4) to connect to a support rod or bracket (not supplied). This must be used to ensure that no load is supported by the turbocharger housing. The support rod or bracket must be securely connected back to a location on the engine or marine transmission to allow the bracket to move with the engine.

If a taller system is required then a dry 90^{O} elbow (not shown) can be used on the turbocharger outlet with the water injected elbow. Full articulation can be utilised to suit most applications

Due consideration must be given to providing flexibility in the exhaust hose, particularly if the engine is flexibly mounted. Where the exhaust hose must pass through a bulkhead immediately behind the engine it is preferable that the arrangement shown in illustration (C) is adopted, using rubber bellows (C1) to provide flexibility.

Note: that the bellows should be in an unstrained condition when fitted, a minimum fall of 5^{o} (C3) is required, and that the point of water injection must be at least 8 inches above the waterline (C2).

Note: A single double hump bellows can be used where space is restricted.

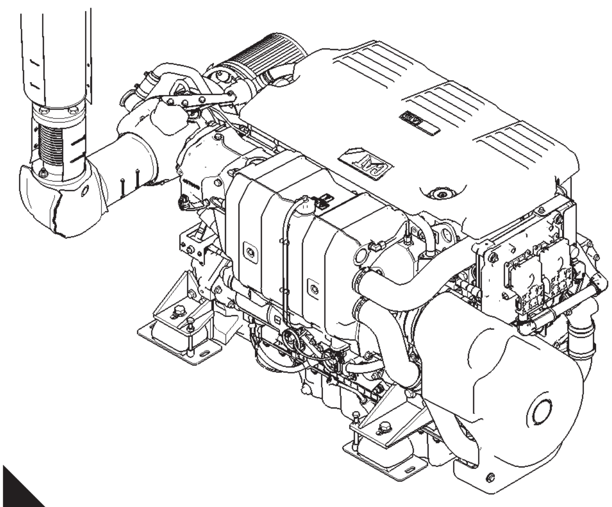
***Caution:* Movement of the engine on the flexible mounts must not be restricted by the exhaust hose.**

Dry Systems

Note: that the system must meet the requirement for the maximum exhaust back pressure to be not greater than 15 kPa, measured within 305 mm (12 inches) of the turbocharger / exhaust outlet.

Caution: The system should be well insulated to avoid fire risk.

Caution : Bellows should be in an unstrained condition when installed, so that the full bellows movement is available to absorb expansion and engine movement.



D

Illustration IM7195

Dry exhaust systems for marine installations need careful design to minimise the disadvantages of enclosing components that are at a high temperature in confined spaces. A typical system is shown in (D).

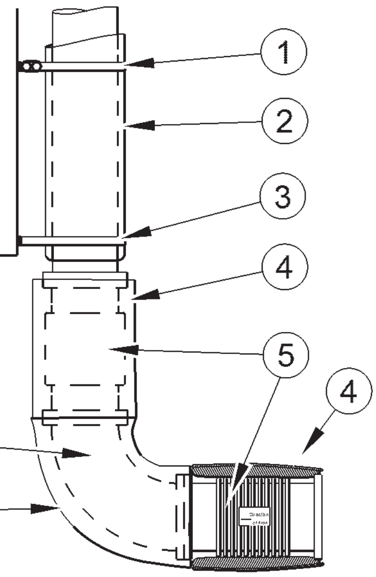
The first part of a dry system should include flexible connections (E5) to permit movement between the engine and the fixed part of the exhaust. Connections of the stainless steel bellows type are suitable, but care must be taken to ensure that they are only required to accommodate movements that do not involve twisting the ends of the bellows relative to each other. Fitting a second bellows 90 degrees to the other one will achieve this. The bellows and elbows should be covered with fire blankets (E4).

If there is a long exhaust run which gains height as it leaves the exhaust manifold, it may be necessary to incorporate a trap to collect condensate and allow it to be drained.

Recommended minimum internal diameter of the turbo outlet exhaust pipe
152 mm (6 ins)

Exhaust Support

Caution: Rigid brackets should only be used on the vertical exhaust system.



E

Illustration IM7108

The weight of the exhaust system should be supported by brackets and not carried by the bellows, as shown in (E).

1 Bracket with link to allow movement due to expansion in the exhaust system (horizontal exhaust systems should be suspended from the deck head using similar brackets).

2 Insulating lagging.

3 Rigid bracket to support the weight of the vertical exhaust system.

4 Heat blanket.

5 Twin stainless steel bellows fitted to avoid torsional load on bellows unit - it is strongly recommended that twin bellows are used.

6 90^{O} elbow.

Part Dry, Part Wet Systems

Note: that the system must meet the requirement for the maximum exhaust back pressure to be not greater than 15 kPa, measured within 305 mm (12 inches) of the turbocharger / exhaust outlet. Minimum volume of exhaust tank should be 3 times the volume of the water in the riser. The tank should be installed near the centre-line of sailing craft.

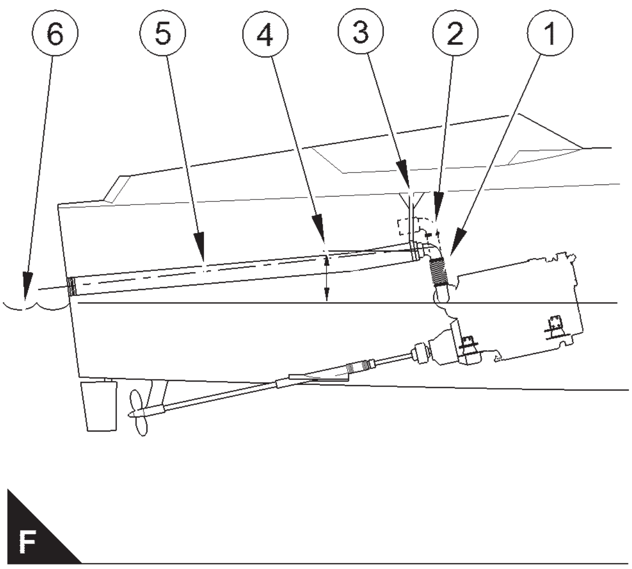


Illustration IM7228

Even where the engine is mounted well below the waterline the advantages of a wet system can still be gained, providing that water injection takes place at a point sufficiently above the waterline.

In these circumstances the part dry, part wet system shown in illustration (F) can be utilised. The modular exhaust components allow a system to be readily constructed, utilising a tall dry riser, followed by a water injection elbow.

(F1) Stainless steel bellows.

(F2) Optional high rise extension - not factory supplied.

(F3) Flexible hanger.

(F4) Point of water injection to be 200 mm (8 inches) minimum height above water line.

(F5) 5^{O} minimum average fall.

(F6) Water line.

Water Lift Systems

Note: that the system must meet the requirement for the maximum exhaust back pressure to be not greater than 15 kPa, measured within 305 mm (12 inches) of the turbocharger / exhaust outlet. Minimum volume of exhaust tank should be 3 times the volume of the water in the riser. The tank should be installed near the centre-line of sailing craft.

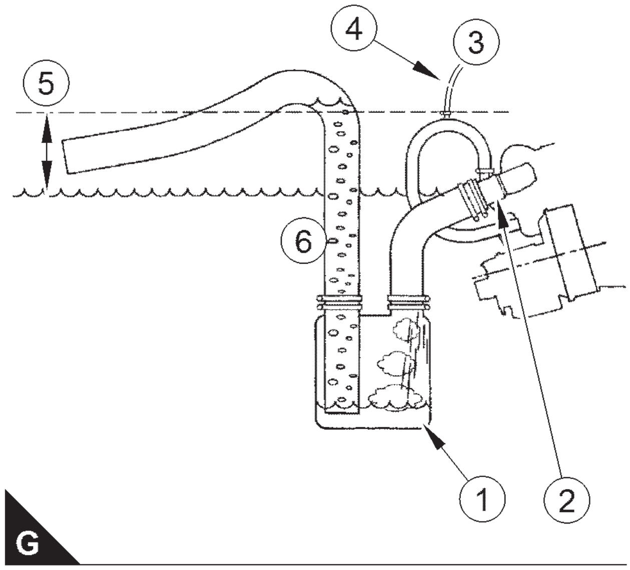


Illustration IM7229

Illustration (G) shows the main features of such a system, which utilises pressure developed by the exhaust gases to force a mixture of gas and water to a height which may be considerably above the engine. When the engine is stopped the exhaust tank contains the water which falls back from the exhaust riser.

If a proprietary unit is used the manufacturers instructions should be carefully followed, but illustration (G) identifies the key features.

(G1) Exhaust tank (water lock).

(G2) Water injection elbow.

(G3) To overboard outlet.

(G4) 1/2” bore siphon break.

(G5) Top of exhaust riser and point at which the siphon break is connected to the engine pipe work must be above the water line under the worst possible conditions (normally a distance of 450 mm (18”) under static conditions will be sufficient)

(G6) Exhaust riser.

Note: Do not overcrank the engine. Overcranking the engine may cause water from the exhaust system to enter into the cylinders.

Silencer

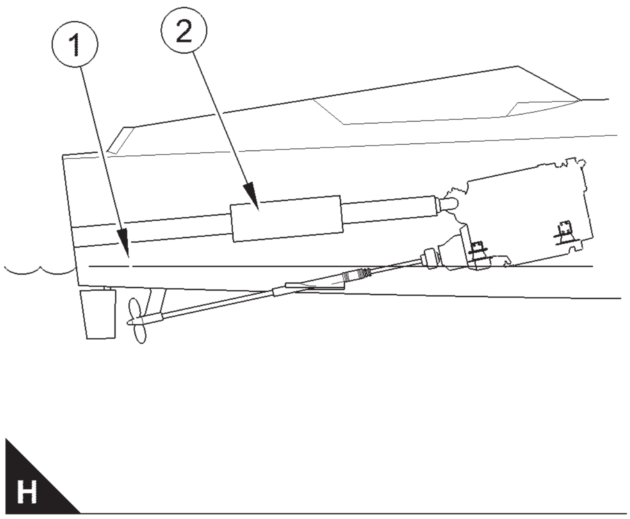


Illustration IM7230

Exhaust noise is one of the principal noise sources of any engine installation. The purpose of the silencer is to reduce the noise of the exhaust before it is released to the atmosphere.

Exhaust noise arises from the intermittent release of high pressure exhaust gas from the engine cylinders, causing strong gas pressure fluctuations in the exhaust system. This leads not only to discharge noise at the exhaust outlet, but also to noise radiation from exhaust pipe and silencer surfaces. A well designed and matched exhaust system will significantly reduce noise from these sources. The silencer makes a major contribution to exhaust noise reduction.

Excessive noise is objectionable in most applications. The required degree of silencing depends on factors such as the application type, whether it is stationary or mobile and whether there are any legal regulations regarding noise emission.

Silencer Selection

The silencer is generally the largest single contributor to exhaust back-pressure. Therefore, required noise reduction and permissible back-pressure must be considered when selecting a silencer. Application type, available space, cost and appearance may also need to be taken into account.

Note: Refer to local legislation on noise limits.

Exhaust outlets should be arranged to keep water from entering the piping system. Rain caps forced open by exhaust pressure will accomplish this; however, they will also introduce additional back pressure into the system and should be carefully evaluated.

6. Fuel Systems

Fuel Connections

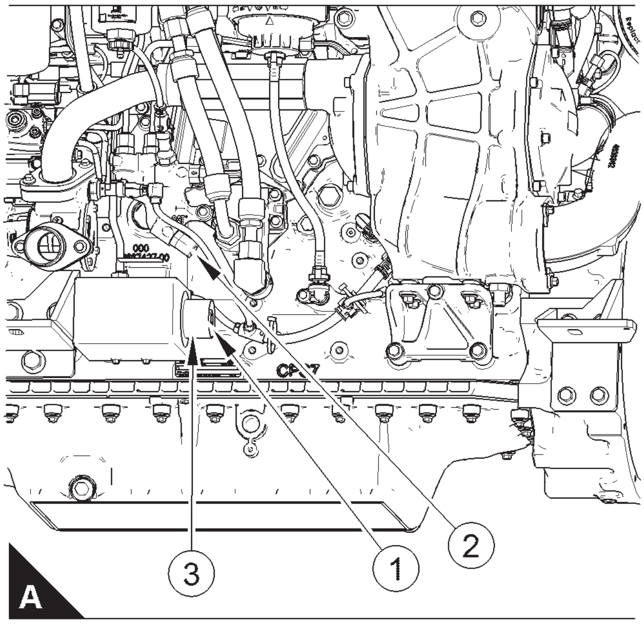


Illustration IM7231

Caution: Ensure that flexible fuel hose routing avoids coming into contact with parts of the engine which can lead to abrasion of the hose.

A common reason for service problems with fuel systems is the use of poor or incompatible connectors, where the pressure tightness depends upon the use of sealing compounds, hose clamps, fibre washers trapped between inadequate and unmachined faces, or compression fittings which have been over-tightened to the point where they no longer seal.

Cleanliness during initial assembly is also of vital importance, particularly when fuel tanks are installed, as glass fibres and other rubbish may enter tanks through uncovered apertures.

It is strongly recommended that the flexible fuel pipes available as an option with the engine are used, which are as follows:

Illustration (A) shows the fuel inlet (A1) and fuel return (A2).

Caution: A protective circular shroud (A3) is attached to the fuel lift pump housing and must be reinstated if removed when removing and replacing the fuel inlet hose connection.

Fuel Feed and Return Sizes

Standard, Fuel Feed & Return

- 3/4”-16, 37^{O} flare (JIC-8 size) straight male connector.

Optional, Flexible Fuel Feed & Return

- 13/16”-16 ‘O’ Ring Faced Seal (ORFS), straight connector.

Optional, Flexible Fuel Feed & Return (female swivel connectors)

- 3/4”-16, 37^{O} flare (JIC-8 size) straight male connector.

Optional, Flexible Fuel Feed & Return (female swivel connectors)

- 13/16”-16 ‘O’ Ring Faced Seal (ORFS), straight connector.

Low Pressure Fuel System

The fuel lift pump should be no more than 2 metres above the minimum fuel level in the tank or 2 metres below the maximum fuel level in the tank in a typical installation.

Fuel Tanks

The more simple the fuel system, the better it will perform in service.

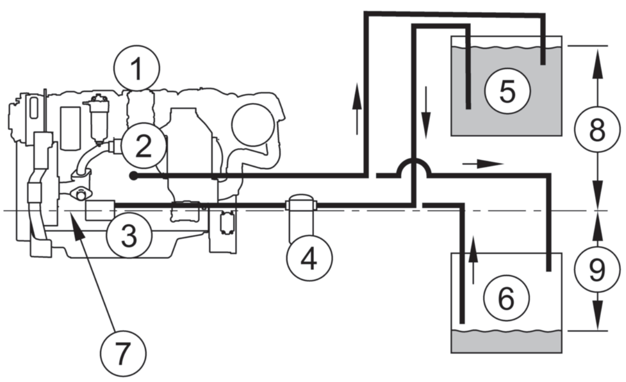
- The filler neck should be raised so that water will not enter when filling.
- The filler cap should seal effectively to prevent water entering when under way.
- A vent pipe should be fitted, again in such a way as to avoid the entry of water.
- The tank should have a sump or angled bottom with a drain tap so that water and sediment can be removed. (This is not always possible).
- Stop cocks can be fitted where necessary. These will also be an alternative way of shutting the engine down in an emergency.
- Internal baffles may be required to prevent fuel surge.
- The tank should have a removable panel to simplify cleaning.
- The fuel pipe work should be as simple as possible with the minimum of valves and cross connections, so that obscure fuel feed problems are minimised.
- A fuel sedimenter (water separator) is required in the fuel system between the fuel tank and the

engine mounted lift pump. To avoid problems when venting air after draining the sedimenter, it should preferably be installed below the normal minimum level of fuel in the fuel tank. (This is not always possible!).

- The tank should have at least two connections; a fuel feed connection, and a fuel return connection. Whenever possible a tank should only supply one engine, but in any case each engine should have its own fuel pipes, from tank to engine.

Tank Location & Fuel Lines

Fuel Tank Location Guidelines



B

Illustration IM7206

1 Engine.

2 Fuel return.

3 Fuel feed.

4 Primary filter.

5 High tank.

6 Low tank.

7 Crankshaft centre line.

8 2 m (78.7 inches) maximum.

9 1 m (39.4 inches) maximum.

- Maximum height of fuel above crank centre-line: 2 m (78.7 inches) (B8) This value is for a typical installation as in the example in illustration (B).

Note: Stop cocks can be fitted where necessary. These will also be an alternative way of shutting the engine down in an emergency. Only shutdown the fuel feed stop cock with the engine running. Shutting the return stop cock could lead to engine damage.

Note: Actual fuel tank height should be calculated using line restriction formulas.

- Minimum depth of fuel below crank centre-line: 1 m (39.4 inches) (B9).
- Maximum feed or return line restriction: 20 kPa (80 in H_2O).

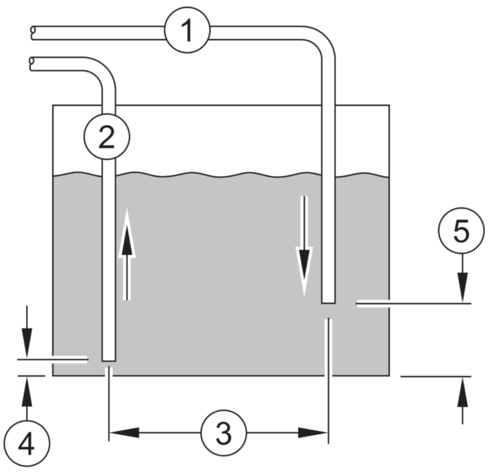
These requirements mean that in practice the following feed and return pressures as measured at the engine connection points must be within these ranges:

Feed pressure must be less than 17 and greater than -30 kPa (at engine inlet).

Return pressure must be less than 37 and greater than -8.5 kPa.

Fuel Supply / Tank Installation

Fuel Tank Guidelines



C

Illustration IM7205

1 Fuel return.

2 Fuel feed.

3 Minimum 300 mm (12 inch).

4 12 mm (0.5 inch).

5 100 mm (4 inch).

The engine requires both a fuel feed and return to the fuel tank. Where multiple fuel tanks are desirable, a single day running tank should be installed which can be filled from the main fuel tanks. If a day tank is required it should be sized to contain sufficient fuel for several hours of engine operation, typically this will require a tank of approximately 150 litres (40 gallons). Smaller tanks should be avoided as high rates of fuel turn-over can lead to the fuel becoming aerated.

Fuel feed and return connections should ideally enter the top of the fuel tank and pass down to the bottom. The fuel feed pick-up (C2) should be just off the bottom of the tank by 12 mm (1/2 inch) (C4) to avoid dirt and water from being sucked up. The fuel return (C1) should also be routed to the bottom of the tank, but again kept off the bottom, by around 100 mm (4 inches) (C5). This helps to avoid the fuel being aerated by the fuel falling into the tank, and also from agitating any dirt located at the bottom of the tank. The fuel feed and return should be horizontally separated by at least 300 mm (12 inches) (C3) to help ensure that any air entrained into the fuel by the return is kept away from the fuel feed pick-up.

Multiple Fuel Tanks

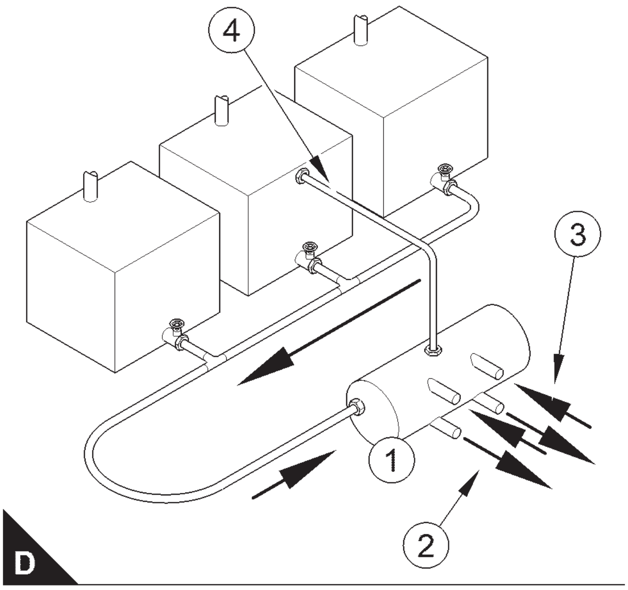


Illustration IM7232

In some cases it is necessary to have a number of fuel tanks in order to achieve the required operating range. In such cases, where possible, one tank should be regarded as the main tank for each engine and the other tanks should be arranged so that they will drain into the main tank by gravity. If a gravity system is not possible, then the system shown in illustration (D) should be used.

The layout shows a collector tank (D1), fed by all the storage tanks and connected to the engine feed (D2) and return systems (D3), but with a vent pipe (D4) taken to any convenient tank.

There is no doubt however, that a simple fuel system should be used wherever possible, as having a completely separate tank and supply to each engine guarantees that if an engine stops, due to running out of fuel or to water or foreign matter in the fuel, the other engine will not be affected simultaneously. This will give some time for appropriate manoeuvring action to be taken. The simple system will also require the minimum number of valves and fittings, which ensures maximum reliability in service.

Typical Basic Fuel Systems

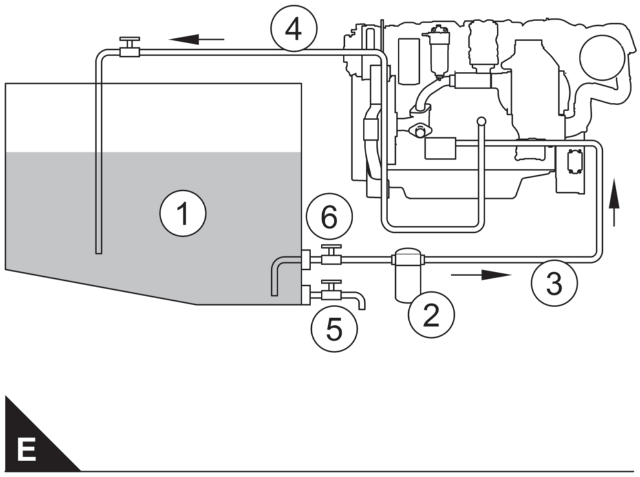


Illustration IM7196

6 Fuel tank.

7 Water separator/pre filter.

8 Main fuel feed.

9 Fuel return.

10 Drain point.

11 Stop cock.

The more simple the fuel system, the better it will perform in service. Figure (E) shows an ideal system. In some applications there may be legislation that requires that fuel lines draw from, and return to, the top of the tank.

The fuel tank may be steel, aluminium, or G.R.P. (Glass Reinforced Plastic) or, alternatively, a rubber bag tank may be used.

The main fuel connection is taken from the rear of the tank (E1) so that all the fuel is available for use when under way when the hull will be at an angle.

The fuel return (E4) is extended within the tank to near the bottom in order to prevent air locks which can arise due to siphoning of the fuel when the engines are stopped

The fuel returned to the tank should be kept away from the main fuel feed, to avoid recirculation.

A drain tube (E5) should be fitted to aid servicing and cleaning.

From the tank the main engine feed line (E3) goes first to a water separator (E2), preferably one fitted with either a thick clear plastic bottom or in accordance with marine societies requirements and a drain cock (use only if allowed by local regulations).

Fuel lines should be chosen and routed to ensure that the maximum line restriction is observed.

Hose internal diameter for SAE-8 JIC fittings is 12.7 mm (1/2”).

Fuel lines should ideally be of stainless steel tube, with flexible hoses connecting to the engine. Restrictive fittings and elbows should be avoided where possible and all bends should have a radius as large as possible.

Copper, brass or zinc plated tube fittings should not be used in the fuel system. Diesel can absorb these materials, whilst they are soluble in the fuel, they can come out of solution in the fuel injector nozzle. This can cause coking of the nozzle, resulting in poor engine performance and adverse emissions.

Stop cocks (E6) may also be fitted where necessary.

This simple fuel system is satisfactory when one or more engines are run from a single fuel tank, and it may also be used when there are two tanks each supplying one engine. In the latter case the system may include a cross connection between the tanks by means of a balancing pipe with a valve at each end. In some installations cross connecting pipes between the two engine feed pipes and the two engine return pipes have been used, but valves are necessary in every line so that the appropriate system may be selected, and the complexity of installation and operation is such that the advantages in operating flexibility are out-weighed by the possibility of obscure problems due to component malfunctions, incorrect operation or engine interaction.

Fuel Systems With Day Tanks

Note: Fuel lines should have bends as wide as possible to minimise restriction.

Note: Day tanks are used in some installations to reduce vacuum or pressure within the fuel system.

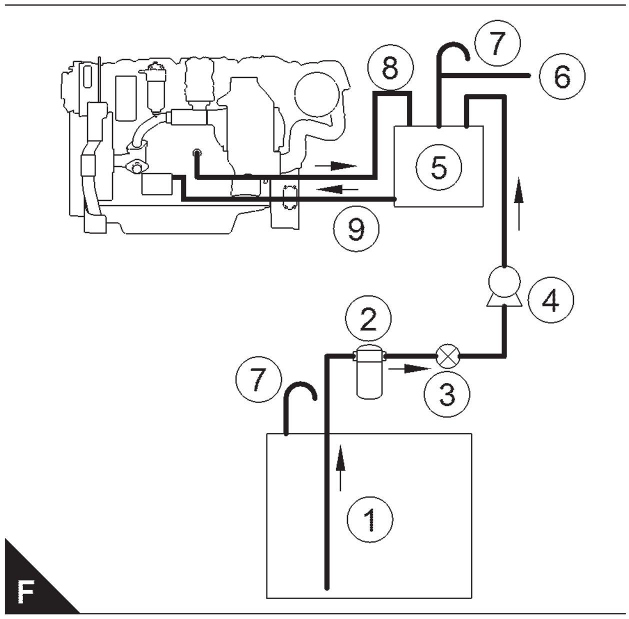


Illustration IM7198

1 Main fuel tank.

2 Water separator/pre-filter (recommended option).

3 Valve.

4 Pump.

5 Day tank.

6 Overflow.

7 Vent.

8 Fuel return.

9 Fuel feed.

Figure (F) shows a fuel system with a day tank situated above the main fuel tank, requiring a pump to transfer fuel into it.

Excessive fuel return line pressure can cause fuel system issues and as such, when the engine is running at low idle no load, the fuel return pressure measured at the connection point on the engine package must not exceed a gauge pressure of 37 kPa (10.9 inches Hg).

Practically, this means the height of the fuel return into the day tank must not be greater than 2.0 metres (6.6 feet) above the engine crankshaft.

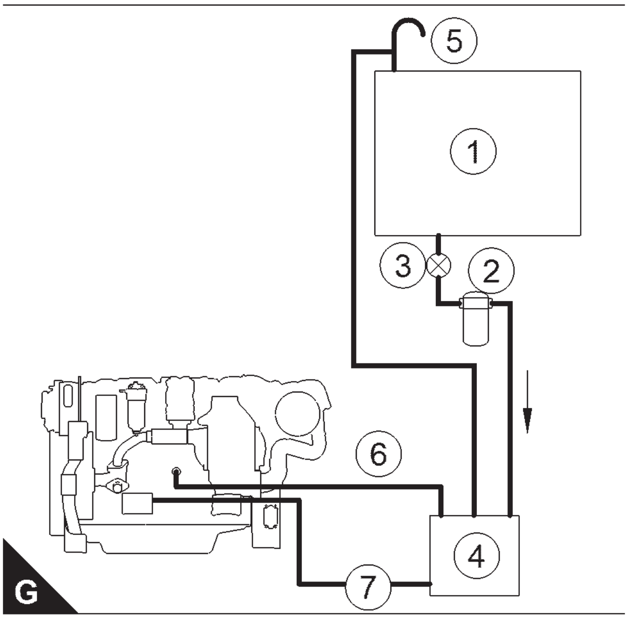


Illustration IM7199

1 Main fuel tank.

2 Water separator/pre-filter (recommended option).

3 Valve.

4 Day tank.

5 Vent.

6 Fuel return.

7 Fuel feed.

Figure (G) shows a system where the day tank is below the main fuel tank and therefore uses gravity to supply fuel to the day tank.

Primary Fuel Filter

A primary filter and water separator must be fitted between the fuel tank(s) and engine fuel inlet connection. A chosen filter must meet the following specification:

- Maximum pressure drop must not exceed 16 kPa (64 in H_2O) with a clogged filter.
- Fuel flow rate: 5 l/min (79.3 gal/hr).
- Emulsified water separation efficiency: at least 85% or better.

Filtration efficiency

5 microns	72%
10 microns	97%
20 microns	100%

Caterpillar offer a filter kit, and replacement filter elements which meets the above specification and is highly recommended.

An optional water in fuel sensor is available for the Caterpillar filter kit which is compatable with the engine electronics and is highly recommended.

The use of a water in fuel sensor is strongly recommended to warn the operator of the presents of water in the fuel. This can help the operator ensure water is removed before it causes damage to the engine fuel system.

7. Engine Cooling System

Engine Cooling

Heat exchanger cooling is when a 'fresh' to 'raw' water heat exchanger is mounted on the engine. The fresh water in the closed circuit is thermostatically controlled which, when closed, a permanent bleed by-passes the heat exchanger minimising the engines warm-up time but maintains sufficient flow through the cylinder block and exhaust manifold. When the engine has reached the correct working temperature, the thermostat opens allowing the coolant over the heat exchanger tubestack which is cooled by sea water.

Cooling Flow Diagrams

Fresh Water

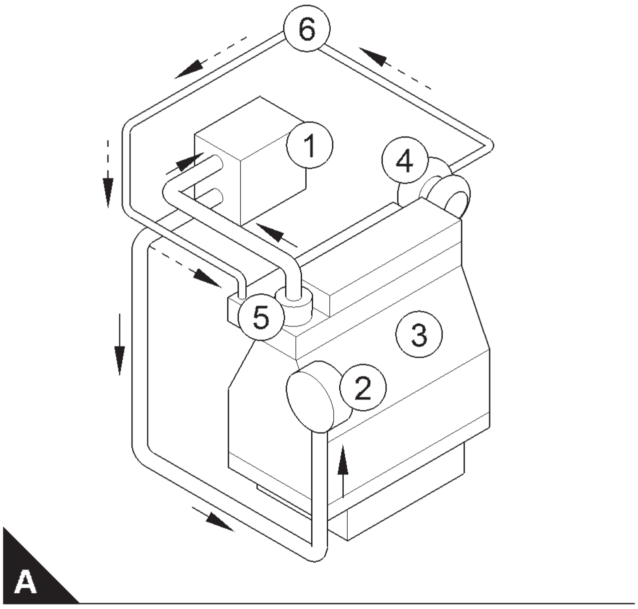


Illustration IM7200

1 Header tank/heat exchanger.

2 Fresh water pump.

3 Engine.

4 Turbocharger.

5 Thermostat.

6 Bleed turbo return flow.

Raw Water

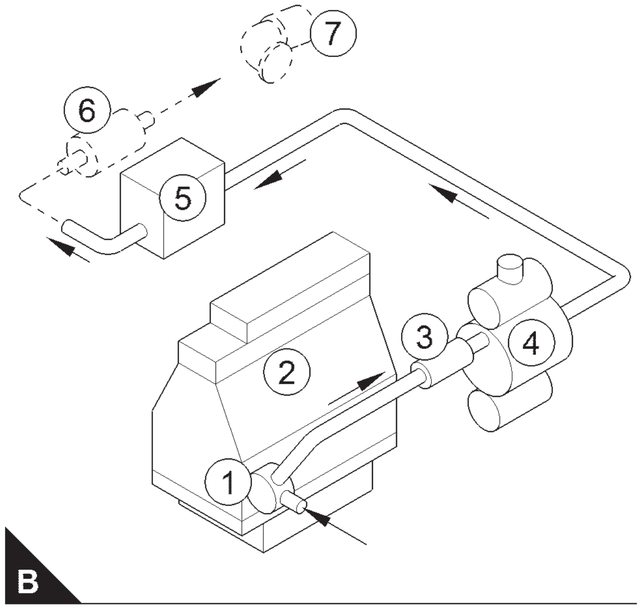


Illustration IM7201

1 Auxiliary water pump.

2 Engine.

3 Fuel cooler.

4 Aftercooler.

5 Header tank/heat exchanger.

6 Gearbox oil cooler (optional).

7 Water cooled exhaust (optional).

Fresh Water System

Caution: Care should be taken when removing the header tank pressure cap. Allow the engine to cool down before removing the cap as hot fluids and steam can be forced out at high pressure if not allowed to settle.

The fresh water circuit cools the engine block, cylinder head, exhaust manifold, turbocharger and header tank/heat exchanger.

Fresh water is circulated through the engine core and turbocharger at start up, and when the normal working temperature is achieved, the thermostat opens and allows water to flow through the heat exchanger.

A hose connected to the header tank pressure cap is provided with the engine. Small quantities of engine coolant may be expelled from the hose in the event of hot shutdown. The hose should be routed to an appropriate receptacle to avoid contaminating the bilge. This should be inspected periodically and emptied if necessary.

Raw Water Systems

Caution: The maximum pressure into the sea water pump should not exceed 1 bar.

Note: Ensure a separate feed for each engine. A shared supply is not recommended.

Note: Where possible mount the strainer so that the top is just above the waterline to facilitate cleaning.

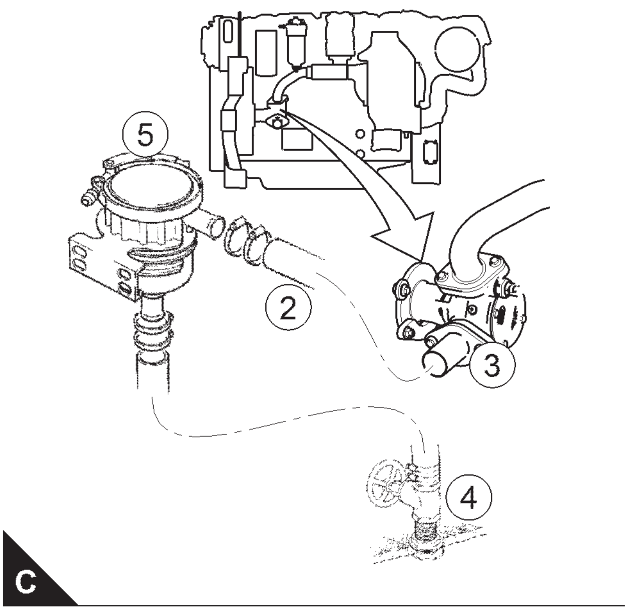


Illustration IM7202

A completely separate sea water system should be provided for each engine to prevent a blockage resulting in the need to shut down more than one engine.

A typical system is shown in figure (C).

The water intake fitting (C4), situated below the water line, should not project appreciably below the bottom of the hull and it should be situated well clear of other components such as shafts, logs and rudders to prevent flow problems at high speeds.

The intake fittings and pipe work should have a minimum bore of 50.8 mm (2.0”) (C2). Inboard of the intake fitting a sea cock must be provided (C4). This should be of the full flow type giving unobstructed passage to the water in the open position with a minimum bore of 50.8 mm (2.0”).

Between the intake fitting and the sea water pump (C3) on the engine, there should be a strainer (C5) which should be easily accessible for routine examination, and should be easily removable.

Seawater Strainers

Caution: It is highly recommended that a sea water strainer is fitted to the inlet side of the sea water pump and have holes of 1.6 mm diameter maximum. The intake pressure must not exceed 1 bar.

Strainers are required in order to protect the seawater pump, aftercooler, heat exchanger and other cooling system components from foreign material in the seawater. The foreign material can plug and/or coat heat transfer surfaces causing overheating of the engine and shortened life of components. If the foreign material is abrasive, it will erode pump impellers and soft metal parts, reducing their effectiveness.

Full-flow strainers are desirable. The strainer screens should be sized no larger than 1.6 mm (0.063 in) mesh for use in closed sea water circuits. The strainer connections should be no smaller than the recommended line size. The use of a differential pressure gauge across the strainers will indicate the pressure drop and enables the operator to determine when the strainers need servicing.

From the sea water strainer, a pipe should be run to the sea water pump inlet connection on the engine. The pipe may either be mainly rigid, for example copper or cupro-nickel, or flexible, but only flexible hose which is reinforced to prevent collapse should be used. The system must be sufficiently flexible to permit the engine to move on its flexible mountings. The sea water pump connection is for a hose with a 50.8 mm (2”) bore, (optional flange connections).

Care should be taken to use compatible materials in the sea water systems to prevent excessive galvanic corrosion. Systems incorporating copper, cupro-nickel, stainless steel Type 316, gun-metal, silver solder, and aluminium brass will generally be satisfactory. Components made from lead, iron, steel, aluminium or its alloys, zinc or magnesium, should be generally avoided.

De-Aeration

Caution: Air in the engine coolant can cause the following problems:

- Air accelerates the corrosion within the engine water passages that can lead to high water temperatures as silt deposits on the surface of the cooler reducing the heat transfer. Premature failure of the engine can occur.
- Air expands more than coolant when heated and may cause loss of coolant from the engine system through the expansion tank overflow.

- In an extreme case, air will collect in one area and cause a loss of coolant flow around the cylinder block resulting in piston seizure and major engine damage.

Caution: Care should be taken when filling the system and should be done slowly to avoid air pockets.

8. Electrical System

Electrolytic Corrosion

⚠ WARNING

Electrical shock can cause severe personal injury or death. Great care should be taken when working on any electrical part of the engine.

Caution: The engine may be damaged by electrolytic corrosion (stray current corrosion) if the correct bonding procedure is not adopted.

Caution: This section on bonding covers a typical system and has been included for guidance purposes only. It may not be appropriate for your boat. As installations vary, it is advised that specific recommendations from a specialist in the subject of electrolytic corrosion are obtained.

Definition of Galvanic and Electrolytic Corrosion.

Galvanic corrosion is caused when two different metals are immersed in a conductive fluid such as seawater (called electrolyte), with a connection between them, an electric current is generated in the same way as a battery.

Electrolytic corrosion (stray current corrosion) is caused by a current from an external source such as the boats battery, shore supply or even the engine itself.

Definition of Bonding, Earthing and Grounding

Note: Earthing and Grounding are different names for the same thing. It is a way of preventing high voltages on machines. 'Earthing' is a more commonly used term in Britain, Europe and most of the commonwealth countries (IEC, IS), while 'Grounding' is a term used in North America (NEC, IEEE, ANSI, UL).

Bonding:

Bonding is joining two electrical conductors together. This is achieved by connecting all the metal parts that are not supposed to be using current during normal use, and bringing them to the same electrical state.

Electricity will not build up in a machine or between 2 different machines that have the same electrical potential.

Earthing:

Earthing protects electrical equipment and operators by discharging the electrical energy to earth. This is done by connecting a part which does not carry current under normal conditions to earth, e.g. frames, enclosures, supports etc. This is normally accomplished by the bonding of a metallic system to earth.

Grounding:

Grounded circuits of machines need to have a return path from the machine to the power source in order to function properly. This is achieved by connecting the live part to earth.

Avoiding Electrolytic Corrosion

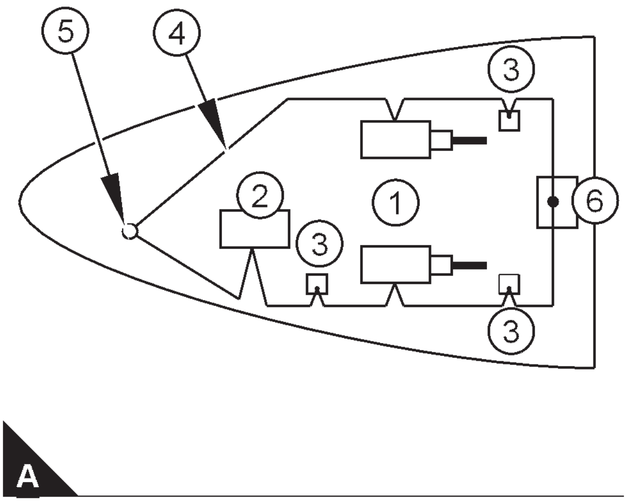


Illustration IM7125

1 Propulsion engines.

2 Genset.

3 Sea cock.

4 Common bonding system wire in a ring as shown.

5 Through the hull metal fittings.

6 Zinc anode.

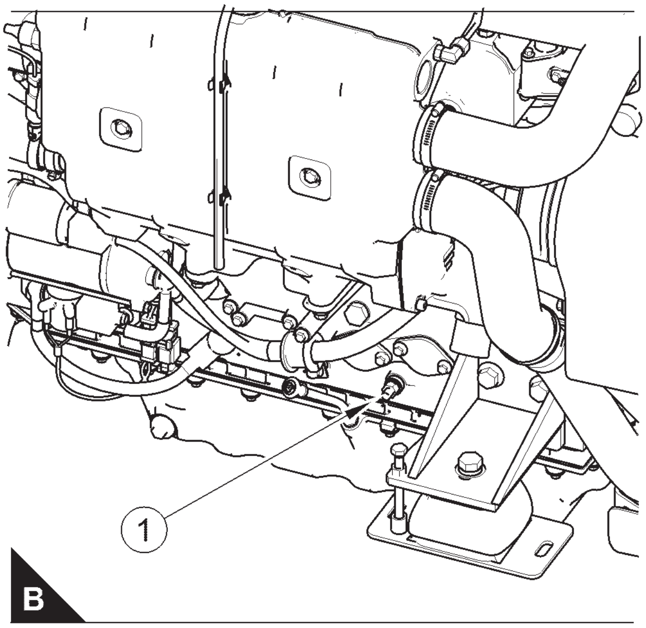


Illustration IM7203

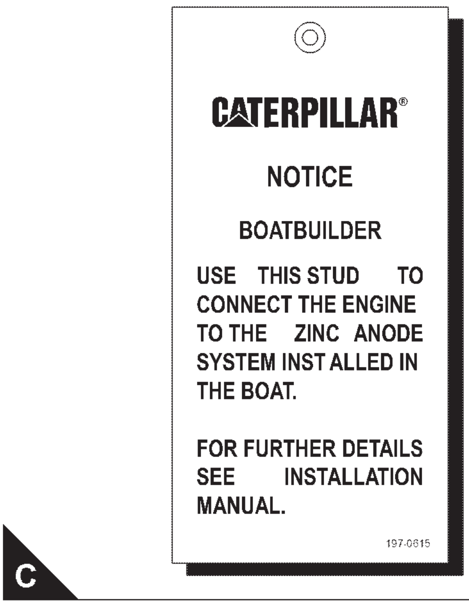


Illustration IM7234

The current that causes electrolytic action is called 'stray current' which can emanate from multiple sources.

The batteries on board the vessel where the negative terminal is earthed to the hull at a central earth terminal can be a source. If other negative connections are made elsewhere on the vessel then the resulting small differences in voltage between the earth terminals can cause the same chemical action as in galvanic corrosion, but it must be stressed that this is not GALVANIC CORROSION but stray current known as electrolysis caused by an external electrical current.

The way to prevent electrolytic corrosion is to ensure a good electrical installation and to bond the engine to the bonding system in the boat which is providing a low resistance connection between all the metals in contact with the sea water. The bonding system should be connected to a zinc sacrificial anode that is fixed to the outside of the hull below sea level. A typical layout is shown in (A).

The bonding should consist of heavy stranded wire (not braiding or wire with fine strands). It is an advantage if the wire is tinned. Insulation is also an advantage and should preferably be green in colour. Although the current carried by the bonding system will not normally exceed 1 amp, the cable sizes should be generous as shown in the table below:

Length of run to zinc anode	Suggested cable size
Up to 30 feet	7 strand / 0.185 mm (4 mm^2)
30 - 40 feet	7 strand / 1.04 mm (6mm^2)

As many of the connections may be splashed with sea water they should be soldered wherever possible and clamped elsewhere with the joint protected from corrosion by neoprene paint or a similar material to exclude water.

Bonding of aluminium boats is a special case as the various appliances on board should be earth free and therefore to avoid stray currents all appliances must be earthed to a single terminal.

Grounding is required on AC voltage for safety reasons if voltages are high. Grounding (or earthing) must not be confused with the term 'earth return'. Earth return carries current, whereas grounding (earthing) does not.

Use the earthing stud bolt (B1) to ground the unit which is identified by a label as shown in (C).

Another source of unplanned current giving raise to a form of stray current corrosion is an earth connection from a shore line. When a shore line is in use the boat system should be protected from earth leakage by an earth leakage switch on shore but as additional safety there should be a switch on board the boat.

Galvanic isolators may also be considered.

Engine Electrical System

⚠ WARNING

Electrical shock can cause severe personal injury or death. Great care should be taken when working on any electrical part of the engine.

Connection Layouts

- The ECM parameters are configured to suit the engine build. If a sensor isn't present on the engine, it will need to be disabled in the ECM otherwise a fault code will be raised.
- Fault codes relating to engine diagnostics will be displayed as a Suspect Parameter Number/ Failure Mode Indicator with a short description via a display or diagnostic lamp.

Fault Codes

A full list of fault codes can be found in the 'Troubleshooting Guide'.

Electrical Wiring Diagrams

Three wiring diagrams are included here to assist in you understanding of the electrical connections.

- Basic wiring diagram.
- Additional electrical features.
- Multiple engine wiring diagram.

WARNING

All wiring must be protected by correctly sized fuses or breakers, to ensure an electrical fire does not occur during an electrical fault.

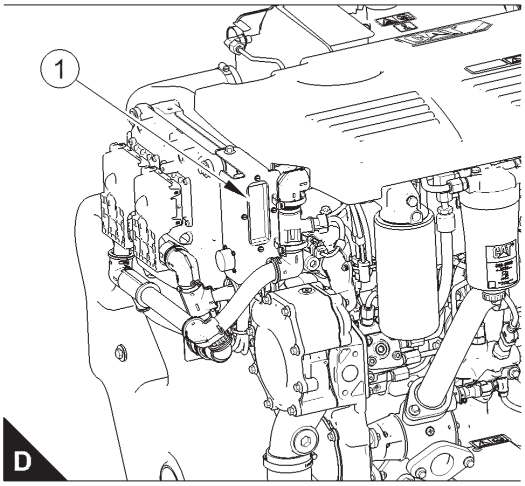
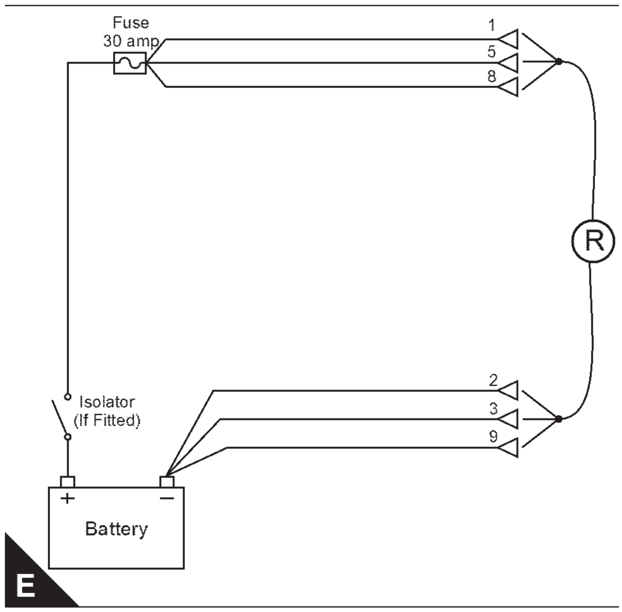


Illustration IM7236

Overview

In order for the engine to operating correctly the electrical system must be correctly installed. Caterpillar offers a wide range of controls, instruments, junction boxes and pre-built wiring harnesses in various lengths. This enables the electrical system to be easily installed. In the absence of these components or if bespoke components are to be used then the following wiring directions should be followed.

The main power and control connections to the engine are made by 70 way connector (D1) located at the front of the engine. This connector provides connectivity for power, throttle(s), lamps, switches and data link to and from the engine. In addition to the 70 way connector, high current power connections are provided at the starter motor.



Basic Engine Wiring

Although the engine's electrical system provides an array of features not all of these need to be implemented in order for the engine to function. The connections required for basic operation are as follows:

Power Supply

Battery power must be supplied to the engine for the electronic control system. This is key to ensuring the engine operates correctly and reliably. The positive supply to the engine should be protected by a suitable fuse or breaker, with a rating of 20 Amp. The basic wiring diagram shows the suggesting positive and negative wiring. It is recommended that 1.5 mm^2 (16 AWG) wire is used to connect to the 70 way connector. There are three pins for the positive connection and three for the negative connection back to the battery. The total circuit resistance of the complete positive and negative wiring to the battery should NOT exceed 50 m Ω for a 12 volt engine or 100 m Ω for a 24 volt engine. This resistance should include the parallel combinations of the three positive wires and three negative wires, as shown in (E) below. This should be born in-mind when designing the cable routing, the table below can help when choosing wire size and length. The positive supply should be taken straight from the battery isolator and should NOT be taken from the starter motor positive. It is strongly recommended it is connected directly to the battery isolator, such that power is unlikely to be interrupted during use and such that the battery can be isolated during idle periods, to ensure the battery is not unnecessarily drained. The negative connections should also be taken straight back to the battery or negative busbar. They must NOT be connected to the starter motor negative.

Wire Gauge		Typical Wire Resistance (mOhms) and Length(s) @ 20°C				
AWG	mm^2	2m	4m	6m	8m	10m
6	13.5	2.8	5.6	8.4	11.2	14
8	9	4	8	12	16	20
10	4.5	8	16	24	32	40
12	3	14	28	42	56	70
14	2	20	40	60	80	100

Key Switch

A key switch or 'ignition' switch should be used to control the engine. The basic wiring diagram shows the recommended connection for the key switch. The key switch positive supply should be protected by a suitable fuse or breaker with a rating of 10 Amp. The key switch must be on for the engine to run. With the key switch on the engine will run once cranked. If the key switch is turned off the engine will stop.

Start Button

A momentary switch should be used to trigger the engine to crank. This could be as part of a combined key switch with a spring loaded 'crank' position, or a separate switch. The basic wiring diagram shows the suggested wiring. The power for the start button should be taken from the same fuse or breaker protecting the key switch. The start button should be held in the on position until the engine starts, then released.

Starter Interlock (Transmission Neutral Switch)

Two pins are provided on the 70 way connector to allow a starter interlock switch to be installed. The basic wiring diagram shows how this should be connected. Typically this feature is used to lock-out the starter motor if the transmission is 'in-gear'. If this feature is not used, then the two pins must be linked.

Stop Button

Although the engine will stop if the key switch is turned off, it is recommend that a separate stop switch is installed. The basic wiring diagram shows the wiring for this switch. The switch should be a momentary type such that it needs to be held until the engine has stopped. If required, additional stop switches can be connected in parallel.

Throttle Signal

In order to control engine speed a throttle signal needs to be supplied to the engine. Typically this is provided by with a PWM or 5 volt proportional signal provided to the primary throttle input. Alternatively the engine speed can be controlled over the J1939

CANBus using the TSC1 message. The basic wiring diagram shows how a throttle sensor should be connected to the engine. Depending on the type of sensor used, it should take it's power supply from either the key switch signal or from the dedicated 5 volt power from the engine. The specification of the sensor should be checked to ensure the correct power source is chosen. Under NO circumstances should the key switch signal and the dedicated 5 volt power be connected together.

The PWM throttle signal should be provided by a sensor or controller with a sinking output driver, at a frequency of 500 Hz +/- 50 Hz. The sensor should give a valid output within 150 ms of power being applied to avoid diagnostics being raised due to a missing signal. 10% duty cycle equates to 0% throttle or request for low idle. 90% duty cycle equates to 100% throttle or request for high idle. Duty cycle lower than 5% or higher than 95% will result in diagnostics being raised to indicate throttle or wiring failure.

The 5 volt proportional throttle signal should have a valid range of 0.5 – 4.5 volts. With 0.5 v equating to 0% throttle or request for low idle. A voltage lower than 0.25V or higher than 4.75V will result in diagnostics being raised to indicate throttle or wiring failure.

Indication Lamps

The engine provides for a total of eight indication lamps. Out of these eight it is strongly recommended that as a minimum the diagnostic and warning lamps are installed. These provide the operator with basic information regarding the engines operation and any warnings or fault conditions. The basic wiring diagram shows how these lamps should be wired. They should take their power from the key switch signal. Each lamp should not exceed a current draw of 200 mA, this limits a lamp to using a maximum of a 2.2 watt bulb. Alternatively LED indicators can be used. It is recommended the diagnostic lamp is RED and the warning lamp is AMBER. The following table shows possible lamp state combinations and their meaning.

Diagnostic Lamp	Warning Lamp	Engine State
OFF	OFF	Normal engine operation with no faults, diagnostics or de-rates
FLASHING	ON	Warning – Engine has detected a problem. (Diagnostic lamp flashes fault code)
FLASHING	SLOW FLASH	De-rate – Engine has detected a problem which is serious and has reduced available engine power to protect the engine. (Diagnostic lamp flashes fault code)
FLASHING	FAST FLASH	Shutdown – Engine has detected a problem which is serious and has shutdown the engine to protect it and the operator. (Diagnostic lamp flashes fault code).

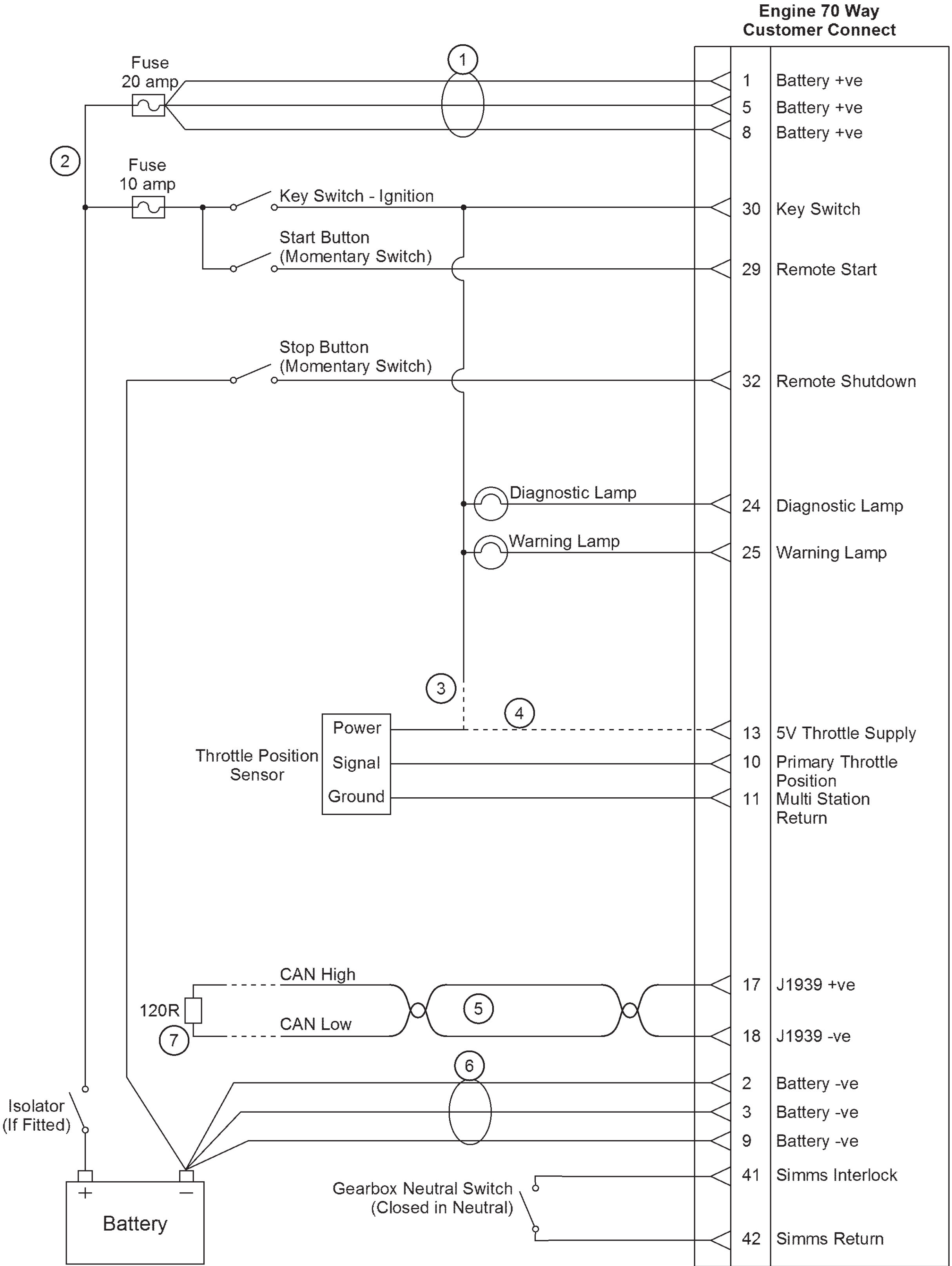
CANBus (J1939)

A J1939 CANBus connection is provided on the 70 way connector. This can be used for integrating instrumentation and controls to the engine. The wiring should conform to the SAE J1939 standard, being a twisted pair with approximately 1 turn per inch. Whilst this twisted pair does not have to be shielded it is recommended that a shielded twisted pair cable is used, especially if the bus run is long, 40 m maximum. The shield should be grounded at one end only to the vessels grounding system, or alternatively the engine block. The end of the bus should be correctly terminated with a 120Ω resistor. The CANBus runs at 250 kbit/s and broadcasts the following J1939 messages. In addition it also accepts the TSC1 message for engine speed control if required (SPNs 695, 897 & 898). In order to TSC1 to be used for speed control it must be enabled via the Caterpillar service tool.

PGN		SPNs Contained In PGN	Description of Data Contained
61473	ESSI	4201, 4203, 4204, 723	Engine Speed Sensor Information - On request
65251	EC1	188, 532, 535	Engine Configuration 1
65226	DM1	987, 624, 623, 1213, 3041, 3040, 3039, 3038,1214, 1215, 1216, 1706	Diagnostic Message 1 - Active Trouble Codes
65227	DM2	987, 624, 623, 1213, 3041, 3040, 3039, 3038, 1214, 1215, 1216, 1706	Diagnostic Message 2 - Previously Active Trouble Codes
65253	HOURS	247, 249	Engine Hours, Revolutions
61444	EEC1	190, 512, 513, 4154	Electronic Engine Controller 1 - Speed, Demand & Load Percentage
65257	LFC	182, 250	Fuel Consumption (Liquid) - Trip and Total Fuel Used
65266	LFE1	51, 183	Fuel Economy (Liquid) - Throttle Valve, Fuel Rate
65243	EFL/P2	157	Engine Fluid Level / Pressure 2 - Fuel Rail Pressure
65165	VEP2	444	Vehicle Electrical Power #2 - Battery Voltage
65271	VEP1	158, 168	Vehicle Electrical Power #1 - Battery & Key Switch Voltage
64925	SEP	3509, 3510	Sensor Electrical Power #1
64976	IC2	3563	Intake / Exhaust Conditions 2 - Intake Manifold Absolute Pressure
65270	IC1	102, 105, 106, 173	Intake / Exhaust Conditions 1 - Intake Manifold Pressure, Temperature & Exhaust Gas Temperature
65263	EFL/P1	100, 111	Engine Fluid Level / Pressure 1 - Oil Pressure & Coolant Level
65262	ET1	110, 174	Engine Temperature 1 - Coolant & Fuel Temperatures
61443	EEC2	91, 92, 29	Electronic Engine Controller 2 - Throttle Position 1, 2 & Load At Current Speed
65247	EEC3	515	Electronic Engine Controller 3 - Desired Operating Speed
64988	MCI	2616, 2617	Marine Control Information - Trolling & Slow Vessel Mode Status
65279	OI	97	Operator Indicators - Water In Fuel
65272	TRF1	127, 177	Transmission Fluids 1 - Transmission Oil Pressure & Temperature
65172	EAC	2435	Engine Auxiliary Coolant - Sea Water Pump Outlet Pressure

65276	DD	96	Dash Display - Fuel Level 1
64735	EFL/P12	6816	Engine Fluid Level / Pressure 12 - Fuel Return Pressure
65200	TTI2	1036, 1037	Trip Time Information 2 - Trip Engine Running Time, Trip Idle Time
65209	LTFI	1004	Trip Fuel Information (Liquid) - Trip Idle Fuel Used
65203	LFI	1029	Fuel Information (Liquid) - Trip Average Fuel Rate
65207	LF	1015	Engine Speed / Load Factor Information - Trip Average Load Factor

Basic Wiring Diagram



1. Each wire = 1.5 mm^2 \16 AWG
2. Each wire = 6.0 mm^2 \10 AWG
3. Key switch supply - Sensor power either +12/24V

   OR
4. -5V supply - ECM, select to suit sensor -ve
5. J1939 to instruments as required - Twisted pair, 1 turn per inch
6. Each wire = 1.5 mm^2 \16 AWG
7. Termination resistor - must be fitted at the end of the Bus

Additional Features

In addition to the basic engine wiring detailed above, required for the engines basic operation, there are additional features which can be installed. The following sections details these features.

Low Oil Pressure Lamp

An additional lamp, see additional electrical features diagram, which activates when low engine oil pressure is detected. The lamp current must be limited to 200 mA, i.e a 2.2 watt bulb maximum.

Low Coolant Level Lamp

An additional lamp, see additional electrical features diagram, which activates when the coolant level is detected as being low. The lamp current must be limited to 200 mA, i.e a 2.2 watt bulb maximum.

Water In Fuel Lamp

An additional lamp, see additional electrical features diagram, which activates when water is detected in the optional primary fuel filter. The lamp current must be limited to 200 mA, i.e a 2.2 watt bulb maximum. (This feature must also be enabled via the Caterpillar service tool)

General Alarm Lamp

An additional lamp, see additional electrical features diagram, which activates whenever there is an active engine alarm to indicate the engine has a problem and requires attention. The lamp current must be limited to 200 mA, i.e a 2.2 watt bulb maximum.

Shutdown Notify Lamp

An additional lamp, see additional electrical features diagram, which activates whenever the engine is not running. This lamp can be used to signal to the operator, maybe in a remote location, that the engine is not running. The lamp current must be limited to 200 mA, i.e a 2.2 watt bulb maximum.

Maintenance Lamp

An additional lamp, see additional electrical features diagram, which activates when the engine is due routine maintenance. The lamp current must be limited to 200 mA, i.e a 2.2 watt bulb maximum.

Maintenance Clear Switch

The additional electrical features diagram shows a maintenance clear switch which can be installed to allow the maintenance indicator to be reset following completion of maintenance. The switch should be closed, bringing the signal to battery negative to reset the indicator. It is recommended this switch is a momentary type and is installed in a protected location to avoid it accidently being activated.

Trip Clear Switch

The additional electrical features diagram shows a trip clear switch. Closing this switch, bringing the signal to battery negative will reset the ‘trip’ totals which accumulate in the engine ECM. These include trip time, fuel used etc. It is recommended this switch is a momentary type and is installed in a protected location to avoid it accidently being activated. Trip totals can also be reset via the CANBus using SPN 988 by PGN 56832.

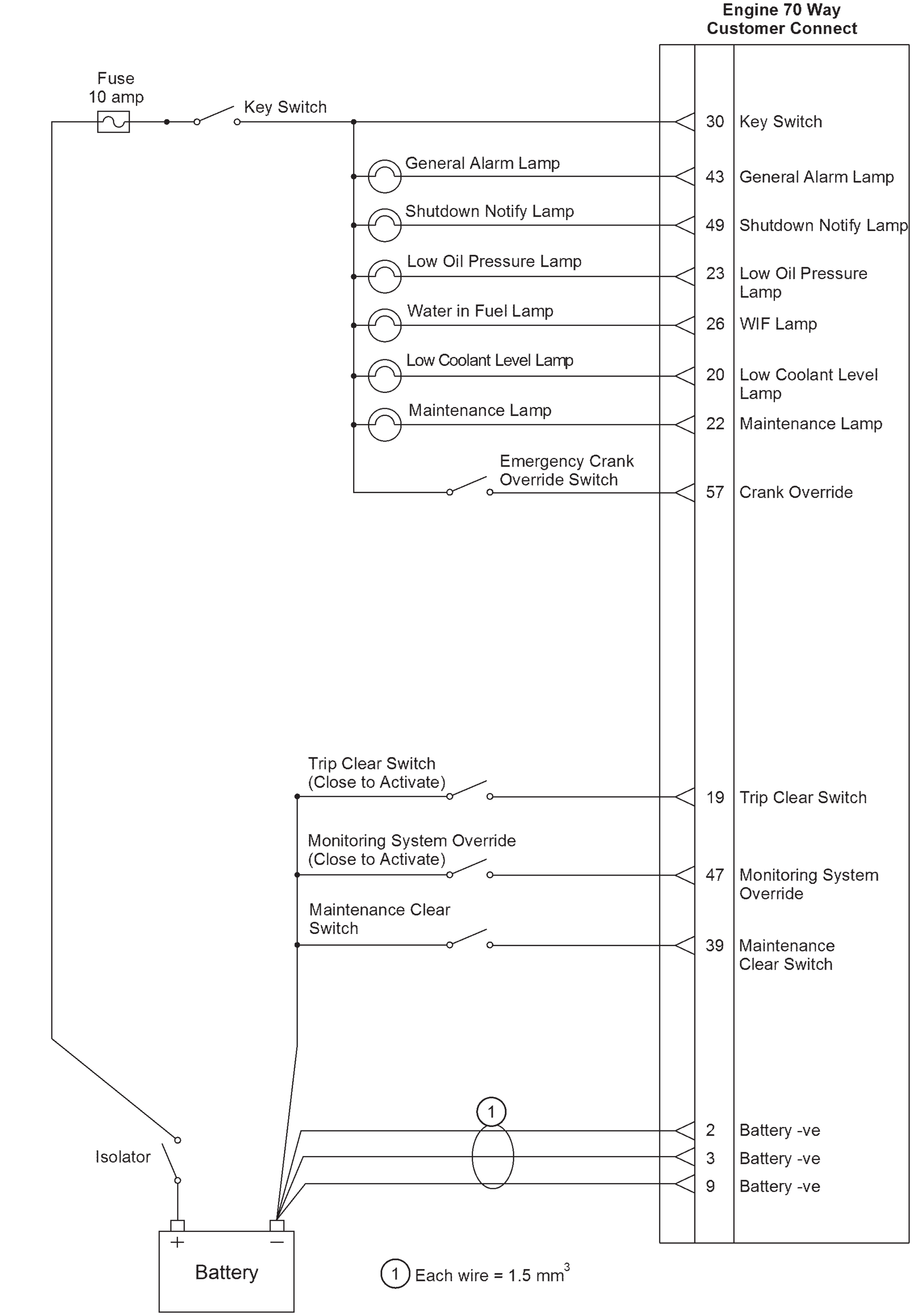
Emergency Crank Override Switch

An input is provided on the 70 way connector to allow the start motor to be directly energised remotely. The input is provided for emergency use only. A switch can be installed as shown in the additional electrical features diagram. The positive side of the switch should take its power from the key switch as shown.

Monitoring System Override

An input is provided on the 70-way connector to allow the engine monitoring system to be disabled. This feature has to be enabled via the Caterpillar service tool. A Caterpillar dealer should be consulted prior to attempting to use this feature as its use can invalidate product warranty.

Additional Features Wiring Diagram



Multiple Engine Installation

Additional features exist for multiple engine installations. These notably include the throttle synchronisation feature which allows all engines to run from one throttle during say a cruise situation to ensure all engines run at exactly the same speed. The multiple engine wiring diagram shows the additional wiring needed for a twin engine installation. Note that the basic and additional wiring as detailed above also applies to twin or multiple engine installation.

Throttle Sync

In order for throttle sync to function both engines need two throttle signals, primary and secondary. The multiple engine wiring diagram shows how these throttle signals should be connected, with the port primary throttle signal being fed to the starboard secondary input and the starboard primary throttle signal being fed to the port secondary input also.

A throttle sync switch needs to be installed to allow the sync feature to be enabled. The twin engine wiring diagram shows how this switch should be installed. When the sync switch 2 signal is connected to battery negative then the given engine will take its speed demand from the secondary throttle signal. If the sync switch 1 signal is connected to battery negative then the engine will takes its speed demand from the primary throttle signal, and will be aware that the other engine(s) are synced to the primary throttle signal. As shown in the twin engine wiring diagram a three position switch should be used to allow, the port engine to be synced to the starboard engine, no synchronisation or, alternatively, the starboard engine to be synced to the port engine.

In order for the throttle sync feature to function it must be enabled via the Caterpillar service tool, to configure the number of engines installed in the vessel and to set their locations, i.e port, centre or starboard.

Diagnostics exist on the secondary throttle signal, as such care is needed for the powering of the throttle sensors. If only one engine is running then it is possible that it would only see one valid throttle signal, the primary, resulting in diagnostics being raised on the failure of the secondary throttle signal. In order to avoid this, diodes can be used, as shown in the twin engine wiring diagram, to provide power to all throttle sensors from either of the engines. The diodes should be installed taking their feed from either the key switch signal or from the engine's dedicated 5Volt throttle power, as shown. A 1N5402 diode or electrically similar should be chosen.

Caution: Under no circumstances should the keyswitch signal be connected to the 5 volt throttle power.

If a central control unit for throttles, for example an integrated transmission controller, is used for the throttle signal feed to the engines, then the addition of diodes for the power supply is unlikely to be needed as the controller will probably have an independent power source.

Throttle synchronisation is not limited to twin engine installations. The detail for other multiple engine installations is not covered here, however the same logic used on the above twin engine installation still applies.

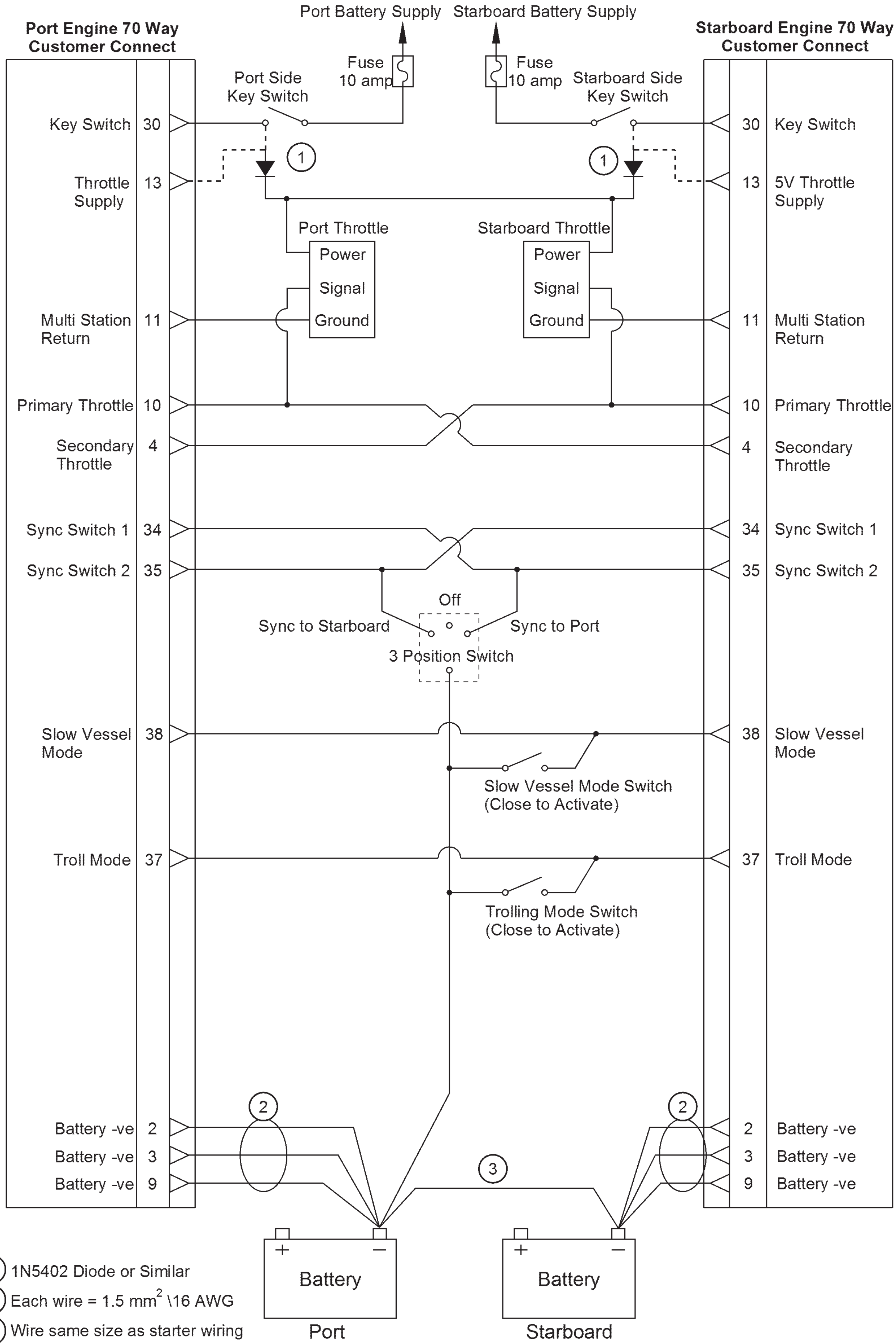
Slow Vessel Mode

Slow vessel mode allows the engine low idle speed to be temporarily reduced to enable slow speed vessel manoeuvring. The twin engine wiring diagram shows how this would be installed. The mode is activated once the signal is connected to the battery negative following a short debounce time. This feature is also available for use on single engine applications. Slow vessel mode can also be enabled via the CANBus using SPN 2883 by PGN 64971.

Trolling Mode

Trolling mode allows the maximum engine speed to be reduced whilst the transmission is trolling, thus limiting the heat being generated. The trolling mode is activated by connecting the signal to battery negative. The maximum engine speed during active trolling mode is configurable via the Caterpillar service tool. This feature is also available for use on the single engine applications.

Multiple Engine Wiring Diagram



1. 1N5402 Diode or Similar
2. Each wire = 1.5 mm^2 \16 AWG
3. Wire same size as starter wiring

Battery and Starter Cables

Starter Batteries

⚠ WARNING

Only persons competent in electrical installations must carry out connections to the starter battery.

⚠ WARNING

The starter battery must be wired correctly otherwise a fire or personal electrocution could result causing injury or death

⚠ WARNING

Ensure that all wiring, connections, safety devices and associated materials conform to the local standards..

⚠ WARNING

Ensure that all wiring is checked prior to operating the alternator.

Caution: Ensure that the wiring is arranged to take up any movement and vibration.

Caution: Ensure that all wiring is protected from any potential abrasion.

Note: Long cable runs from the battery to the starter should, where possible, be avoided.

Note: Where starting at temperatures below freezing is an important requirement, a 24 volt system is the preferred choice

The performance of starter batteries is commonly expressed by the current in amperes that they will supply under specified conditions.

The standard by which battery performance is commonly stated:-

- SAE J537 is similar except that the current is only maintained for 30 seconds and the voltage is allowed to fall to 7.2 volts.

Batteries for temperatures down to -5°C (23°F)	
12 Volt	24 Volt
One battery - 520 Amps SAE J537 (CCA)	Two 12V batteries in series - each 315 Amps SAE J537(CCA)

Batteries for temperatures down to -15°C (5°F)	
Two 12V batteries in parallel, each 520 Amps SAE J537 (CCA)	Two 12V batteries in series, each 520 Amps SAE J537 (CCA)

Starter Cables

Battery Connection

Note: Main supply for starter and supply for control and start aid must be run separately from the battery.

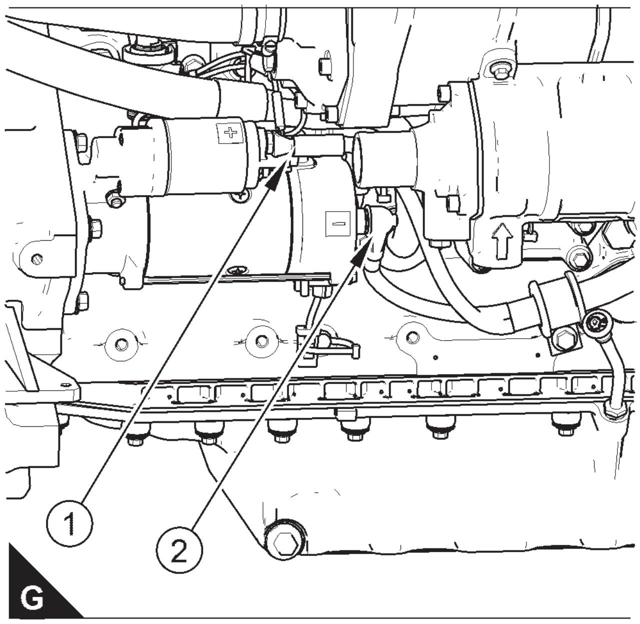


Illustration IM7154

The battery connection points for the starter motor are shown in illustrations (G).

1 Positve.

2 Negative.

Battery Isolator Switches

A switch should be fitted in the positive lead to the starter, as close to the battery as is convenient. The switch should be suitable for a momentary current of at least 1000 Amps.

Battery Cables

The total resistance of the two leads from the battery to the engine should not exceed 0.0017 ohms. In practice, this means that the total length of the starter cables (positive and negative) should not exceed 5 metres if the commonly available 50 mm^2 cable is used. Longer cable runs, which should be avoided if possible, will require either double cables or a heavier cable, in order to comply with the total resistance of 0.0017 ohms.

Mounting the battery close to the starter is the preferred option.

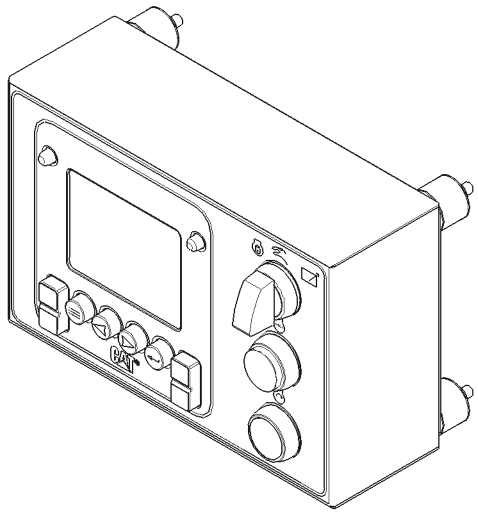
Starter cables for 12 or 24 volt systems				
*Maximum total length		Cable size metric	Nominal C.S.A.	
Metres	Feet		mm^2	in^2
4.9	16.2	19/1.78	50	0.078
6.9	22.7	19/2.14	70	0.109
9.4	30.8	19/2.52	95	0.147

Nominal resistance in ohms		Approx. equivalent size	
Per metre	Per foot	English imperial	America B&S SAE
0,000344	0.000105	19/0.07	0
0,000246	0.000075	61/.044	00
0.000181	0.000055	19/0.1	0000

*The length of all cables in the starter circuit (whether positive or negative), should be added together to give the ‘Total Length’.

9. Control Systems

MECP I (Marine Engine Control Panel)



A

Illustration IM7207

Note: Ensure that any secondary control panels do not override the primary control panel.

Note: An engine which is equipped with a pod drive unit may have a separate control system

The Marine Engine Control Panel (MECP I) is an engine mounted panel that gives the user key switch, start and stop functionalities in the engine room. The MECP I also has the ability to monitor engine communications to show the user valuable vessel information and alert the user of any diagnostic warnings.

The MECP I has been developed to use the J1939 protocol and is programmed accordingly.

For more detailed information on this panel. Please refer to publication LEBM0037.

10. Power Take-Off (Optional)

PTO Fitting Instructions

⚠ WARNING

For safety reasons, all moving parts should be shielded by a guard.

Caution: Load should be applied gradually, not suddenly. Maximum load is 100%.

Note: Fitting the PTO should be undertaken by a qualified marine engineer.

Note: Remove all traces of paint from the mating faces before assembly.

Note: It is highly recommended that a TVA (Torsional Vibration Analysis) is carried out on all equipment that is expected to run on the PTO.

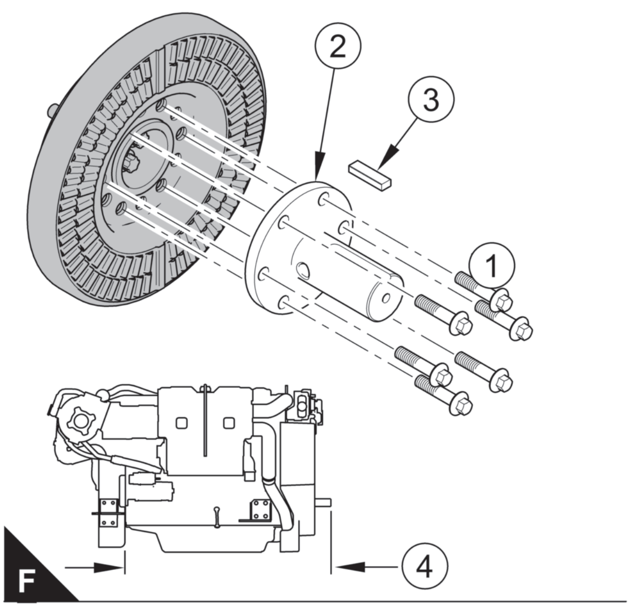


Illustration IM7187

1 M12 bolts, tighten to 115 Nm

2 PTO shaft.

3 Key.

4 Rear face of the engine block to the end of the PTO is 1144 mm

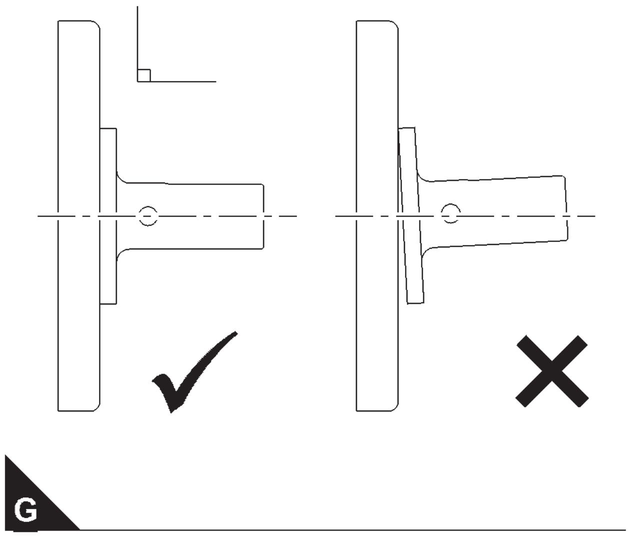


Illustration IM7124

Provision for Power Take-Off

Caution: Care must be taken when mounting additional machinery to avoid stress and vibration.

Caution: Suitable material must be used to make a support frame bearing in mind the weight and type of equipment to be utilised.

Caution: It is strongly recommended that crankshaft axial and belt driven loads are analysed, and it is advisable to carry out a full TVA (Torsional Vibration Analysis) on any additional driven loads.

PTO’s are used predominately to drive auxiliary equipment such as refrigerators, water makers, additional alternators and hydraulic winch motors for example.

The way in which the additional machinery is mounted is important in order to avoid stress to the engine and vessel.

Belt Driven

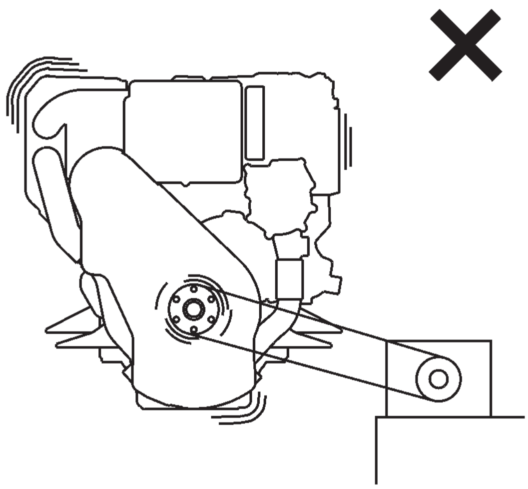
Caution: Additional inertia must not be added to the PTO shaft without specialist advice. Consult your distributor if you need advice about non-standard drive arrangements.

Note: Maximum recommended offtake 2 kW per belt.

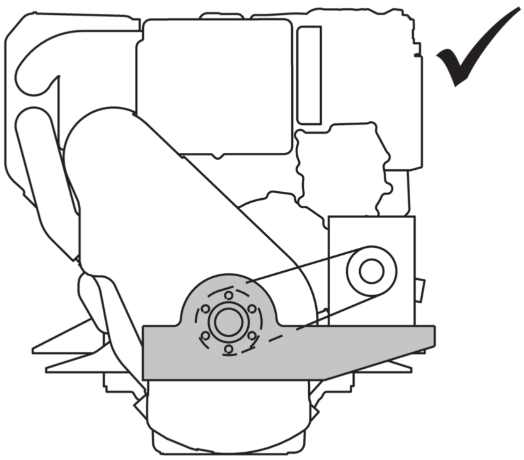
Note: Multiple belt driven accessories, should as far as possible, be distributed evenly on either side of the engine to minimise side loads

Note: If you are in any doubt, please contact your distributor.

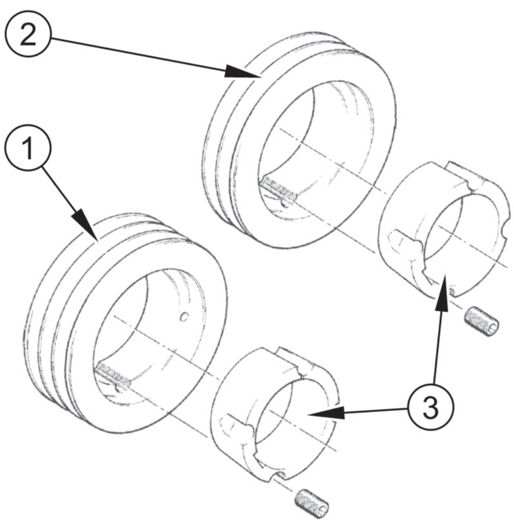
Note: The frame shown is not a factory option.



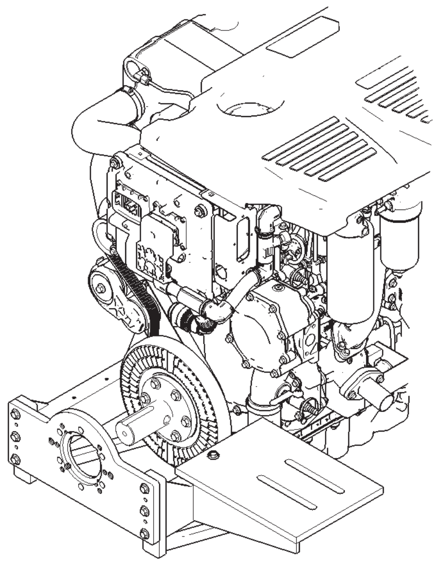
H
Illustration IM7188



I
Illustration IM7189



J
Illustration IMC7160



K
Illustration IM7190 Typical example

Illustration (H) shows how mounting the machinery to the hull will create excessive vibration which could lead to damage of the engine or vessel.

The arrangement shown in (I) should be adopted with a suitable frame mounted on the engine to support the additional equipment.

Illustration (J) shows a taper lock drive for belt driven PTO arrangements.

Five inch ‘A’ section pulley with 3 grooves (J1) and five inch ‘B’ section pulley with 2 grooves (J2) are recommended, secured in place by taper locks (J3).

In this case, the maximum power which can be taken will be limited by the belts and it will be necessary to calculate for marginal applications.

A suggested frame is shown in (K), which shows a typical arrangement which is not a factory option.

Note: The belt guard has been removed for clarity. In service a belt guard must be used for safety reasons.

The frame has been bolted between the engine and mounts in place of the engine feet with a platform to secure the equipment.

Axial Driven

Caution: Additional inertia must not be added to the PTO shaft without specialist advice. Consult your distributor if you need advice about non-standard drive arrangements.

Caution: If the engine utilises flexible mounts, careful attention is required to prevent strain on the crankshaft nose.

Note: The frame shown is not a factory option.

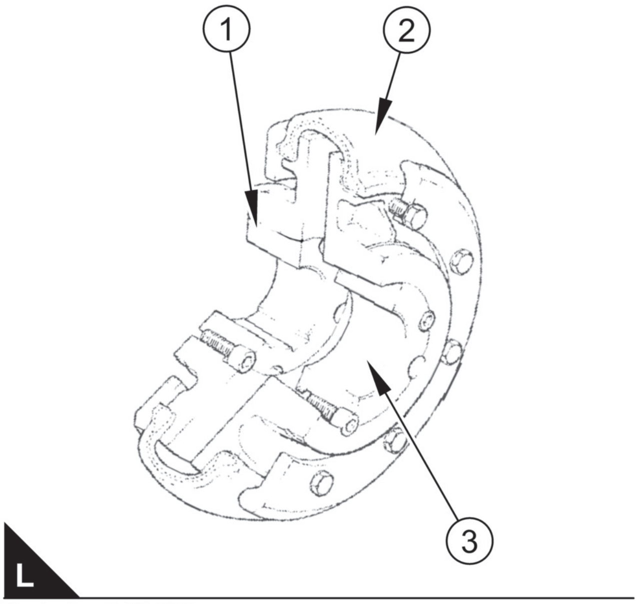


Illustration IMC7159

A tyre type coupling should be used as shown in (L) and this prevents strain on the crankshaft nose.

1 Taper lock flanges.

2 Flexible tyre.

3 Taper lock.

Polar Diagram

It is possible to take power from the front crankshaft pulley via belts, chains, etc. This type of PTO generates a bending moment on the front of the crankshaft. Excessive bending moments can cause issues excessive stresses on the crankshaft.

The maximum load that can be applied to the crankshaft by a belt driven device is 1290 N radial load or 107 Nm torsional load, whichever is lower. The radial load is taken at the middle of the PTO pulley, 241 mm from the front face of the cylinder block. Loads taken from an auxiliary pulley (mounted forwards of the standard crankshaft pulley) should be scaled using moments taken from the front face of the cylinder block.

The load needs to be taken into consideration if the engine takes a belt drive arrangement.

11. Cabin Heater/Calorifier

⚠ WARNING

Pressurised system! The engine must not be run until the cabin heater system is installed. Hot coolant can cause serious burns, injury or death.

Fittings on the engine allow a calorifier to be connected to the engine, as shown in illustration (A).

The hose connections to the calorifier must be of a radiator or heater hose quality and 1/2” bore, and must be installed so that chafing will not occur.

1 Supply to calorifier.

2 Return from calorifier.

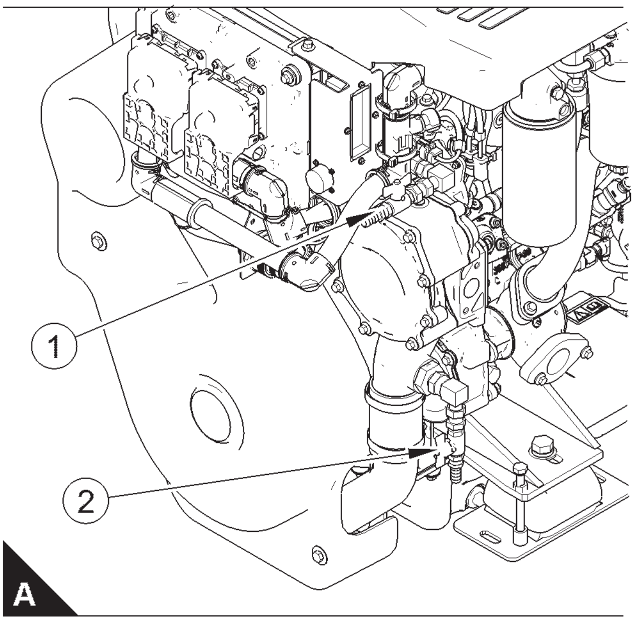


Illustration IM71P10

12. Reference Material

The following information is provided as additional reference to subjects discussed in this guide.

- Price List can be accessed via Power Net.
    - https://engines.cat.com/marine

- Application and installation can also be accessed via Power Net
    - https://engines.cat.com/marine/application

- Installation drawings (GA's) can be retrieved from the Engine Drawing Design Centre (EDDC). A paid subscription is required to download drawings from this site.
    - https://enginedrawings.cat.com/

- Technical Marketing Information (TMI), engine performance data.
    - http://tmiweb.cat.com/

- Service Information System (SIS Web), service and maintenance information.
    - https://sis.cat.com/

California

Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.